A Water Quality and Aquatic Resource Inventory For the Proposed Murphy Creek Project on the Columbia River, B.C. 1982-1983 Investigations

Prepared for

B.C. Hydro
Vancouver, British Columbia

by

R.L. & L. Environmental Services Ltd.
17312 - 106 Avenue
Edmonton, Alberta

August 1984

Canadian Cataloguing in Publication Data

Main entry under title:
A Water quality and aquatic resource inventory for the proposed Murphy Creek Project on the Columbia River, B.C.

Bibliography: p.
ISBN 0-7726-0169-0

1. Fishery resources - Columbia River Watershed.
2. Aquatic resources - Columbia River Watershed.
3. Fishes - Columbia River Watershed - Effect of water quality on. I. B.C. Hydro. II. R L & L Environmental Services.

SH224.B7W37 1984 333.95'61 C84-092259-0

TABLE OF CONTENTS

		Page
LIST OF TABLES		iii
LIST OF FIGURES		v
ACKNOWLEDGMENTS		vi
1.0	INTRODUCTION	1
1.1	Background	1
1.2	Study Area	1
1.3	Purpose and Scope	1
1.4	Terms of Reference	2
2.0	METHODOLOGY	3
2.1	Study Scheduling	3
2.2	Water Quality Sampling	3
2.3	Mysid Sampling	6
2.4	Benthic Macroinvertebrates	7
2.5	Fish Sampling	9
2.5.1	Collection Techniques	9
2.5.1.1	Boat Electrofishing	9
2.5.1.2	Backpack Electrofishing	10
2.5.1.3	Trapping	12
2.5.2	Location of Spawning Areas	13
2.5.3	Spawning Escapement Estimates	13
2.5.4	Fish Marking	13
2.5.5	Fish Life History Data	14
2.5.5.1	Collection Phase	14
2.5.5.2	Analysis Phase	14
3.0	RESULTS AND DISCUSSION	16
3.1	Water Quality	16
3.1.1	Chemical	16
3.1.2	Dissolved Gas Levels	18
3.2	Mysid Sampling	25
3.2.1	Seasonal Recruitment	25
3.2.2	Mysid Life History	30

TABLE OF CONTENTS (cont'd)

		Page
3.2.3	Utilization By Fish	32
3.3	Benthic Macroinvertebrates	34
3.4	Fish Resources	39
3.4.1	Seasonal Species Composition and Status	39
3.4.2	Spawner Enumeration	45
3.4.2.1	Rainbow Trout	45
3.4.2.2	Kokanee	50
3.4.3	Fish Movements	54
4.0	SUMMARY AND CONCLUSIONS	56
LITERATURE CITED		59
APPENDICES:	Appendix A - Terms of Reference	63
	Appendix B - Stomach Content Analysis	66
	Appendix C - Abundance and Composition of Benthic Invertebrates	68
	Appendix D - Electrofishing Catch and CUE	74

List of Tables

		Page
Table 2.1	Water quality parameters and methods of analyses.	5
Table 3.1	Water quality analyses - Columbia River and Kootenay River, 1982 and 1983.	17
Table 3.2	Dissolved gas measurements from the Columbia and Kootenay rivers in the vicinity of Castlegar, July 1982 to April 1983.	19
Table 3.3	Dissolved gas measurements from a channel transect, located approximately 300 m below Hugh Keenleyside Dam, for 10 February and 29 April, 1983.	22
Table 3.4	Affected area of body for fish displaying gas bubble disease during sample periods in July and August/September 1982 and April 1983.	23
Table 3.5	Numbers and density of Mysis relicta collected in drift nets (all sets 15 min) during daytime sets in the Columbia River downstream from Hugh Keenleyside Dam (Site M1), 2 September 1982.	26
Table 3.6	Numbers and density of Mysis relicta collected in drift nets (all sets 15 min) during nighttime sets in the Columbia River downstream from Hugh Keenleyside Dam (Site M1), 1982 and 1983.	27
Table 3.7	Numbers and density of Mysis relicta collected in drift nets (all sets 15 min) during nighttime sets in the Columbia River near the Castlegar-Robson ferry (Site M2), 1982 and 1983.	29
Table 3.8	Number and size of eggs or brood carried per female mysid collected from the Columbia River, February 1983.	31
Table 3.9	Mean length and biomass of mysids preserved during each of the four sample periods, 1982 and 1983.	33
Table 3.10	Summary of abundance, number of taxa and Shannon-Weaver diversity ($\bar{d}$) for Hess cylinder samples collected during 1982 and 1983.	36
Table 3.11	Summary of abundance, number of taxa and Shannon-Weaver diversity ($\bar{d}$) for Ekman grab samples collected during 1982 and 1983.	37

List of Tables (cont'd)

		Page
Table 3.12	Fish species encountered in the Columbia River and tributaries, 1982 and 1983.	40
Table 3.13	Numbers of fish captured or observed by various sampling methods, and percentage composition of total catch (by species) in the Columbia River and selected tributaries, 1982 and 1983.	41
Table 3.14	Night electrofishing catch and CUE (No. fish per km) for all sample sections in the mainstem Columbia River, 1982 and 1983.	43
Table 3.15	Adult rainbow trout captures in Norns Creek, 15 April to 5 May, 1983.	47
Table 3.16	Water temperature and stream depth (at trap site) in Norns Creek, 15 April to 6 May, 1983.	48
Table 3.17	Numbers of kokanee spawners enumerated in Norns Creek in 1982.	51
Table 3.18	Estimates of kokanee escapements in tributaries of the Columbia River, 1976 to 1982.	53
Table 3.19	Summary of fish recaptures, Columbia River, 1982 and 1983.	55

List of Figures

		Page
Figure 2.1	Murphy Creek Fisheries Study 1982 and 1983 sample locations.	4
Figure 2.2	Murphy Creek Fisheries Study 1982 and 1983 intensive sample area sample locations.	11
Figure 3.1	Total dissolved gas level (percentages) for four sites in the Columbia and Kootenay rivers from July 1982 to April 1983.	20
Figure 3.2	Seasonal variation in night electrofishing catches for rainbow trout and kokanee in the Columbia River, for periods 1980-81 and 1982-83.	44
Figure 3.3	Seasonal variation in night electrofishing catches for mountain whitefish in the Columbia River, for the periods 1980-81 and 1982-83.	46

ACKNOWLEDGMENTS

The following employees of R.L. & L. Environmental Services Ltd. contributed to the collection of field data and preparation of the report.

Gary Ash	- Project Manager, Senior Author
Curtiss McLeod	- Editor
Terry Clayton	- Project Biologist, Junior Author
Larry Hildebrand	- Project Biologist
Fred Salekin	- Local Assistant•
Carol Henderson	- Typist

Laboratory identifications and counts were made by C. Pattenden, A. Mobach, and K. Cooper.

The authors also would like to thank employees of the B.C. Fish and Wildlife Branch, specifically H.A. Andrusak, R.A. Lindsey, P. Stent, and D.W. Campbell, for their cooperation throughout the study and providing background information on the fisheries resources in the area. We are also very grateful for the hospitality provided by the Salekin family and Mr. F.B. Giraud of Robson.

The authors also would like to thank H.A. Smith, J.S. Mathers, and D. Maxwell of B.C. Hydro for their helpful suggestions throughout the project and for their critical review of the draft report.

B. C. Hydro reproduced the final report.

1.0 INTRODUCTION

1.1 BACKGROUND

During the period 1980 to 1982, B.C. Hydro conducted detailed environmental studies relating to the proposed Murphy Creek hydroelectric project on the Columbia River in southern British Columbia. In the spring of 1980, R.L. & L. Environmental Services Ltd was contracted to undertake the fisheries component of these studies. The results of the investigations and assessment of probable impacts of the development were reported by Ash et al. (1981) in a document entitled "Fisheries inventory and impact assessment in relation to the proposed Murphy Creek Project on the Columbia River, B.C."

As a result of a number of data deficiencies identified in the inventory and impact assessment report, B.C. Hydro commissioned additional environmental studies in June of 1982 to supplement the aquatic resource inventory data compiled during the previous studies.

1.2 STUDY AREA

The study area consisted of the mainstem Columbia River from the Hugh Keenleyside Dam (Km 57)[a] downstream to Trail (Km 18), the Kootenay River from the Brilliant Dam downstream to the Columbia River, and the tributaries entering into the Columbia River within this area. A detailed description of the physical habitats in these watercourses is given in Ash et al. (1981).

1.3 PURPOSE AND SCOPE

The primary purpose of the study was to provide additional inventory information to supplement the existing water quality and aquatic resource data within the study area, and to identify year-to-year fluctuations within the expanded inventory. A secondary purpose of the study was to provide a general assessment of the extent of downstream movement of Mysis relicta through the Hugh Keenleyside Dam into the study area. Field studies were conducted on a

---

[a] In this report, distances along the mainstem Columbia River are given in kilometres upstream of the Canada-U.S.A. border.

seasonal basis and included summer and autumn of 1982, and the winter and spring of 1983.

1.4 TERMS OF REFERENCE

The terms of reference for the study as originally supplied by B.C. Hydro are provided in Appendix A. However, at the proposal stage, it was identified that fulfillment of a number of the requirements in the terms of reference was not possible within the time-frame and budgetary constraints of the program. As a result, item #3 under Inventory - (iii) Fish Resources:

> "Estimates of numbers of fish passing from Arrow Lake into the study area should be carried out"

and item #2 under (b) Effect of Development:

> "Estimate the level of recruitment of fishes and invertebrates into the study area from Arrow Lake",

were deleted from the study.[a]

Some changes also were made in the water quality parameters analysed at the B.C. Hydro laboratory; these included a reduction in the various nitrogenous components analysed. Also, the spring 1983 water quality samples were collected by B.C. Hydro staff and analysed as part of an ongoing more detailed water quality program within the study area. As a consequence, there were minor differences in parameters analysed and methodology used.

The original terms of reference required sampling of Mysis relicta during the spring and summer periods only. After discussion with B.C. Hydro biologists, it was decided that the effort would be better expended sampling during each of the four seasons (i.e., spring, summer, fall, winter) in order to identify seasonal differences in recruitment and use in the study area.

---

[a] A separate study of fish passage through the Hugh Keenleyside Dam was commissioned by B.C. Hydro during 1983.

2.0 METHODOLOGY

2.1 STUDY SCHEDULING

Field investigations were conducted seasonally, with the survey periods as follows:

(1) Summer 1982 (14-21 July)
(2) Fall 1982 (26 August-5 September)
(3) Winter 1983 (9-11 February)
(4) Spring 1983 (14 April-6 May)

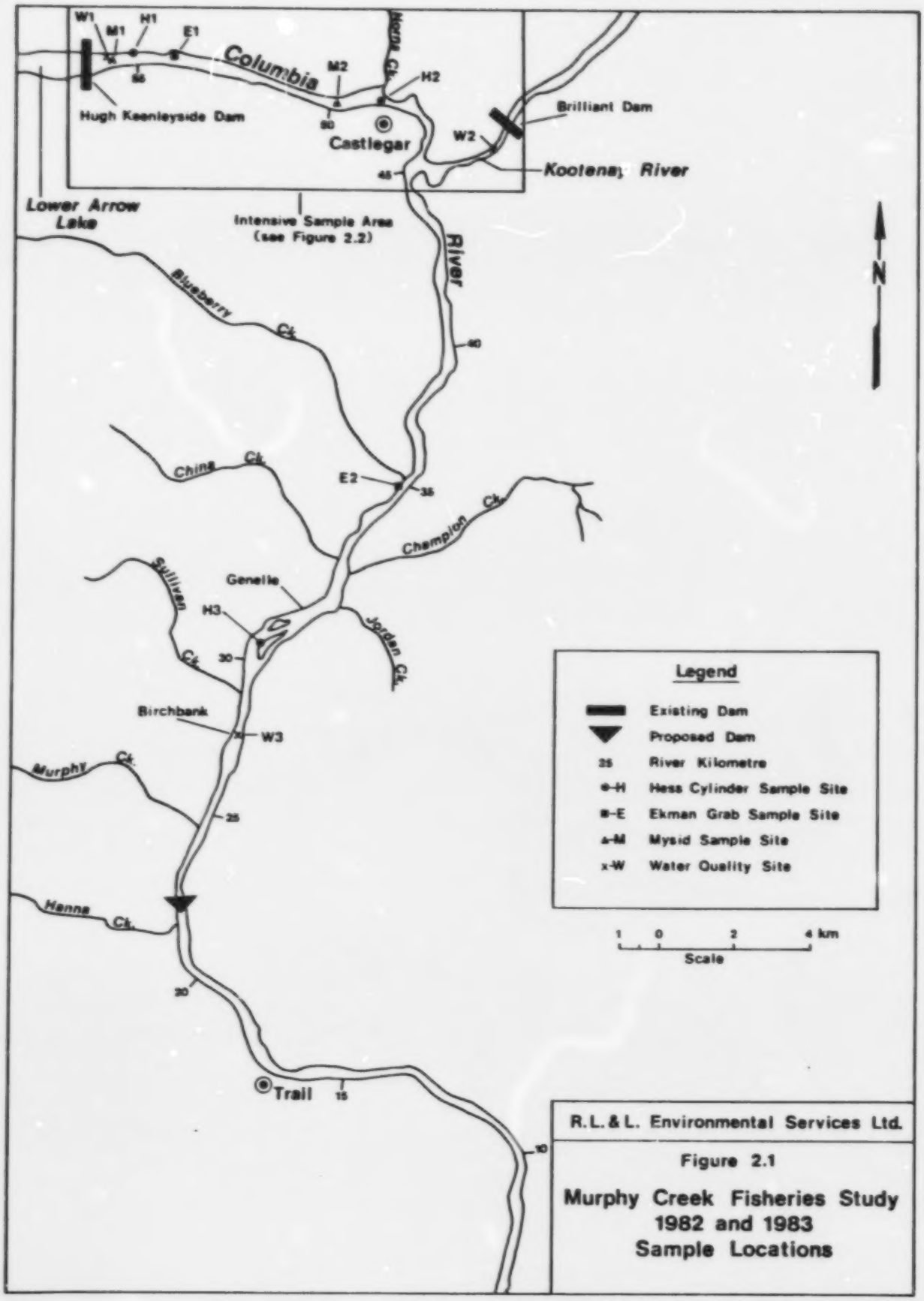
Sampling effort was greatest in the spring and fall, since the majority of spawning activity by sport fish occurs during these periods. In addition, water samples for chemical analyses were collected by B.C. Hydro staff on 31 May 1983. Office analyses of the field data were conducted between field periods and during the summer and fall of 1983.

2.2 WATER QUALITY SAMPLING

Water samples for detailed chemical analyses were collected at two sites on the Columbia River (near the Hugh Keenleyside Dam and at Birchbank), and at one site on the Kootenay River downstream of the Brilliant Dam (see Figure 2.1). The samples were collected on a seasonal basis (i.e., 26 July and 3 September, 1982; 10 February and 31 May, 1983[a]). Sub-surface water samples were collected at each site in pre-washed plastic bottles. The samples were then preserved, placed in a cooler containing refrigerated ice packs, and shipped to the B.C. Hydro Research and Development Chemistry Laboratory at Surrey, B.C. All analyses were conducted by the B.C. Hydro laboratory with the exception of total organic carbon which was determined by CanTest Ltd. in Vancouver. The parameters analysed and the analytical methods are outlined in Table 2.1.

---

[a]B.C Hydro personnel collected the water samples on 31 May 1983 as part of a detailed water quality program for the Columbia River.



R.L.& L. Environmental Services Ltd.

Figure 2.1

Murphy Creek Fisheries Study 1982 and 1983 Sample Locations

Table 2.1. Water quality parameters and methods of analyses

Parameter	Preservation	Method or Instrument
pH		- Fisher Accumet 420 digital pH meter with glass and calomel reference electrodes
Conductivity		- Y51 Model 31 conductivity bridge with platinum-iridium electrode
Total suspended solids		- weight of residue (after drying at 103-105°C) retained by 0.45 µm cellulose acetate filter membrane
Total dissolved solids		- weight of residue after filtered sample evaporation at 103-105°C
Total phosphate		- persulphate digestion, ascorbic acid reduction (colourimetric)
Total dissolved phosphate		- as total PO_4 after 0.45 µm filtration
Total particulate phosphate		- the difference between total and total dissolved PO_4
Dissolved ortho-phosphate		- as total dissolved PO_4 but without digestion
Total nitrate/nitrite	- 2 mL/L conc. H_2SO_4	- phenoldisulphonic acid method (colourimetric)
Dissolved nitrate/nitrite	"	- as total NO_3/NO_2 after 0.45 µm filtration
Particulate nitrate/nitrite	"	- the difference between total and dissolved NO_3/NO_2
Total Kjeldahl N	"	- digestion, distillation, specific ion electrode
Ammonia N	"	- distillation, specific ion electrode
Organic N	"	- ammonia removal, digestion, distillation, specific ion electrode
Silica		- $NaHCO_3$ digestion, molybdosilicate method (colourimetric)
Total organic carbon	- 2 mL/L 10% HNO_3	- Dohrman Organic Carbon Analyzer, Model DC-80

In addition to the chemical analyses of waters in the study area, in situ measurements of the dissolved gases were conducted at each of the water quality sites. Dissolved oxygen levels were measured using the azide modification of the Winkler method. Total dissolved gas concentrations were measured using a Model 300B Tensionometer manufactured by Novatech Designs Ltd. (Victoria, B.C.). During each survey period, the calibration of the instrument was checked using the barometric pressure reading at the Castlegar Airport.

2.3 MYSID SAMPLING

To provide information on the seasonal recruitment of Mysis relicta from Lower Arrow Lake into the upper section of the Columbia River, a sampling program was implemented using stationary nets. Two sites, M1 and M2, below the Hugh Keenleyside Dam, were sampled (Figure 2.1).

Samples were collected using three nets, each with an aperture of 0.18 m^2, attached to a heavily weighted anchor line. The nets simultaneously sampled the surface (1 m depth), bottom (1 m off bottom) and midpoint of the water column. Each net was 2.1 m in length, constructed of 0.75 mm mesh, and tapered down to a terminal collection bucket. Sampling was conducted at two hour intervals commencing at 1800 h, 2000 h or 2200 h (depending on the onset of darkness) and continued through until 0200 h. The nets were lowered and raised using a hand operated winch, and installed for a 15 minute period. The volume of water filtered by each net was estimated using a General Oceanics Model 301 digital flow meter, positioned centrally in the mouth of the net. In addition, surface velocities were recorded with the aid of a Marsh-McBirney electromagnetic velocity meter. The mysids collected in each of the samples were enumerated on site and then preserved in 5% formalin.

In the laboratory, 100-200 mysids from each survey period (when available) were measured to the nearest 0.5 mm from the tip of the rostrum to the end of the telson using a dissecting microscope at 40 x magnification. The sex of mysids larger than 12 mm was determined based on the presence of enlarged 4th pleopods in the males (Morgan 1981) and the presence of a brood pouch (marsupium) in the females (Morgan and Beaton 1978). The number of eggs or

brood present in the marsupium of the females was noted, and the stage of development of the brood was classified as follows (Mauchline 1980):

Stage I

This is the early embryo, at first egg-like but later with rudiments of antennae and abdomen developing. It is still within the egg membrane which is shed at the end of this stage.

Stage II

The larvae has hatched from the egg membrane by puncturing it with the abdomen. The antennae and thoracic appendages develop during this stage and the eyes become pigmented. This stage terminates in a moult.

Stage III

The moulted larva now has the eyes on stalks. No lith is present in the developing vesicle of the statocyst in the uropods. This stage also terminates in a moult that takes place as, or shortly after, the larvae are released from the marsupium.

Biomass of mysids was estimated using the length-dry weight relationship presented by Lasenby and Langford (1972) for Char Lake, Ontario, which is as follows:

$$Y = 0.00345\ X^{2.84}$$

where Y = dry weight of the mysid in mg,

X = total length of the mysid in mm.

2.4 BENTHIC MACROINVERTEBRATES

The benthic macroinvertebrate fauna was sampled at five sites along the margins of the Columbia River within the study area (Figure 2.1). In shallow-water areas with a granular substrate (i.e., sites H1 to H3), sampling was conducted using a Hess-type cylinder sampler (area = 0.1 m^2; mesh aperture 0.210 mm). This sampler thoroughly encloses the sampling area and does not allow organisms to drift into or be washed out of the sampled area. Cylinder

samplers of this type are recommended by the U.S. Environmental Protection Agency for quantitative sampling in shallow-water benthic habitats (Weber 1973). Three samples were collected at each site, with the substrate being thoroughly stirred to a depth of about 5 cm.

Two sites with a sand/silt substrate (E1 and E2) were sampled using a 15 cm x 15 cm Ekman grab (area 0.023 m^2) lowered from the boat. Three samples were collected at each site and were individually washed in a screen bottom bucket with a mesh aperture of 0.6 mm.

The benthic macroinvertebrate samples were preserved in the field in 5% formalin, then sorted in the laboratory and preserved in 75% ethanol. Identifications generally were made to genus, or to species when practical. The more difficult groups to identify, such as the Nemata (nematode worms), Oligochaeta (bristle worms), Acari (mites), and some of the Diptera (true flies), were left at higher taxonomic levels. Chironomidae (midge) larvae were identified to subfamily and tribe levels. Keys used for identification were Usinger (1956), Edmondson (1959), Allen and Edmunds (1962, 1963, 1965), Gaufin et al. (1972), Mason (1973), Merritt and Cummins (1978), Wiggins (1977), Baumann et al. (1977) and Pennak (1978).

Diversity was calculated using the Shannon-Weaver function as expressed by Lloyd et al. (1968). The formula is

$$\bar{d} = \frac{C}{N}(N \log_{10} N - \Sigma n_i \log_{10} n_i)$$

where C = 3.321928, N = total number of individuals, and n_i = number of individuals in the i^{th} taxa. In the interpretation of diversity data, samples with less than 100 organisms were noted. As the U.S. Environmental Protection Agency points out, "the estimate of $\bar{d}$ improves with increased sample size and samples containing less than 100 specimens should be evaluated with caution, if at all" (Weber 1973). To provide the maximum sample size for the calculation of diversity values, the data from the three samples from each site were pooled. Although the level to which identifications are made can affect diversity values, comparisons are valid when the level of identification employed is constant (Hughes 1978). Hence, diversity values can be used as a criterion for comparing sites in a particular study, but it would be erroneous to compare values between studies using different levels of identification.

2.5 FISH SAMPLING

2.5.1 COLLECTION TECHNIQUES

2.5.1.1 Boat Electrofishing

The primary objectives of the electrofishing program were 1) to monitor seasonal changes in species composition and relative abundance of fish populations in the study area, 2) to compare these data with previous years data to identify any trends in the sportfish populations, and 3) to obtain specimens in good physical condition for tagging.

The sampling gear consisted of a 5.5 m aluminum jet boat, and a Smith-Root Type VI electrofisher which converted 220 VAC from a 4500-W generator into pulsed DC. Electrical current was directed into the water through a hand-held anode which consisted of a 25.4-cm-diameter metal ring covered with 0.64-cm mesh nylon seine material and attached to a 3.0-m insulated pole. The cathode lead was connected directly to the transom of the aluminum riverboat. Pulse configuration consisted of a triangular wave (fast rise, slow decay) at 60 Hz. The majority of shocking was conducted with the unit producing 650 to 825 VDC at 2 to 4A. These parameters have been shown to be effective in attracting fish within netting distance while causing minimal physiological damage to the fish (Taylor et al. 1957; Vincent 1971), and were similar to those used during the previous electrofishing surveys, thereby allowing comparison of the electrofishing catch data.

The boat electrofishing procedure consisted of drifting downstream through defined sampling sections. The boat was maintained near shore, with the anode positioned between the boat and shoreline. The mesh size of the capture net resulted in a negative bias for small fish (i.e., less than 15 cm in length). Fish escaping the electric field or avoiding the netter were enumerated by crew members and recorded as "observed" at the end of the sample section. The same was true for juvenile fish or cyprinids that were not collected. Captured fish were transferred immediately to on-board live tanks and were processed upon completion of a sample section or when the holding capacity of the tanks was reached. Fresh water was added periodically to replenish the oxygen supply and reduce stress. Habitat types and preferences of

the various species were observed and noted. Water temperature was recorded with a pocket thermometer to the nearest 0.5°C. Electrofisher settings, amperage produced, and sampling effort (seconds and kilometres shocked) were recorded. Overall sampling efficiency was estimated on a scale of one to four. Factors affecting sampling efficiency include wind induced wave action (reduced visibility and identification), extent of foam on the water, and the depth of water sampled (dependent on discharge).

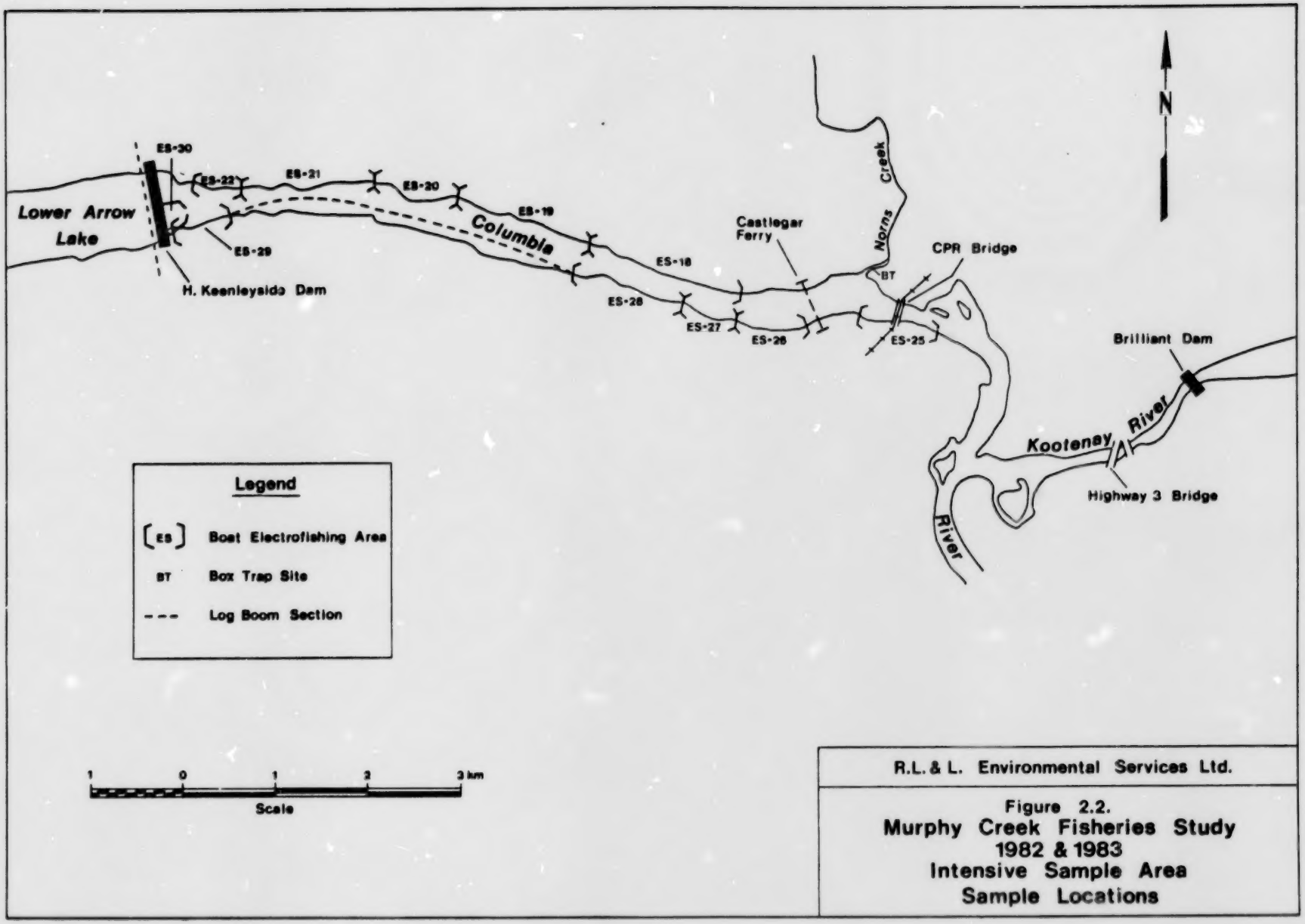
The boat electrofishing was conducted during night periods. Previous sampling in the study area has shown that fish are present in shallow water areas during this period, and capture avoidance is greatly reduced.

A total of 11 boat electrofishing sections were sampled on the mainstem Columbia River between the Hugh Keenleyside Dam and the CPR Bridge at Castlegar (Figure 2.2). The sections sampled during the present study corresponded to those sampled intensively during the 1980-1981 period (Ash et al. 1981) and included electrofishing sites ES 18-22 on the north side of the river and ES 25-30 on the south side of the river. Each of the sites were sampled twice during each of the summer and fall 1982, and spring 1983 survey periods, thereby allowing comparison of data collected during the previous studies.

2.5.1.2 Backpack Electrofishing

Backpack electrofishing was conducted in the lower sections of tributaries to the Columbia River to obtain information on use by adult rainbow trout for spawning. This method also was used in Norns Creek to obtain an estimate of the size of the rainbow trout spawning run by mark/recapture techniques.

Backpack electrofishing was conducted using a Smith-Root Type VII electrofisher. Sampling efficiency in most of the tributaries was only moderately effective due to high water velocities and boulder substrates. The unit produced 0.5 to 1.0 A at voltage settings of 400 to 600 VDC. Sampling efficiency was reduced further in streams where conductivity was low or depths exceeded 1.0 m (e.g., Norns Creek). For the most part, average stream depths were substantially less than 1.0 m and were not a factor limiting capture



R.L. & L. Environmental Services Ltd.

Figure 2.2.
Murphy Creek Fisheries Study
1982 & 1983
Intensive Sample Area
Sample Locations

success. Fish escaping the electric field or avoiding the netter were enumerated and recorded as "observed" at the end of the sample section. Captured fish were handled in a manner similar to that described previously for the boat electrofishing method.

2.5.1.3 Trapping

One upstream and one downstream-oriented fish trap (box traps) were utilized in the lower sections of Norns Creek during the period 14 April to 5 May 1983. The purpose of the fish trapping program was two-fold. Firstly, it would provide adult rainbow trout for tagging to develop additional data on the timing and extent of rainbow trout movements in the Columbia River study area. Secondly, it would provide data for the estimation of the size of the rainbow trout spawning run into Norns Creek.

The upstream oriented trap measured 1.2 m x 1.2 m x 2.4 m and the downstream oriented trap measured 1.2 m x 1.2 m x 1.2 m; both were constructed of wood. Funnel entrances measured 30 cm x 30 cm reducing to 30 cm x 8 cm. The traps initially were set at the perimeter of the main channel in locations characterized by moderate current velocities, and depths between 0.4 and 1.0 m. A fence constructed of Vexar plastic netting was angled across the entire stream channel to direct fish into the traps.

The traps were checked and cleaned daily. Water and air temperatures, water visibility, estimated trap efficiency, and water depth at the trap entrance were recorded at each inspection. The efficiency of traps in Norns Creek during the spring of 1983 was substantially lower than in 1981 as a result of high water levels and the transport of large quantities of sand and silt. The sediment originated from an upstream area where a major bank slump had occurred. The deposition of the sediment on the downstream side of the fence resulted in the redirection of most of the flow within a confined channel which continued to wash out various sections of the fence. As a result, the trap was not fully operational during the entire sample period. Although a concurrent trapping operation had been planned for Champion Creek, after consultation with the B.C. Hydro Biologist (Mr. H. Smith), it was decided that additional effort be spent on maintenance of the Norns Creek trap. This, in conjunction

with very high seasonal flows, precluded the operation of a trap in Champion Creek. In place of the trapping program in Champion Creek, the study crew conducted visual and backpack electrofishing surveys to document any adult rainbow trout present in that system during the study period.

2.5.2 LOCATION OF SPAWNING AREAS

Areas utilized by rainbow trout and kokanee for spawning in Norns Creek were located by direct observations of fish spawning in the creek. Also, a helicopter reconnaissance of the mainstem Columbia River, Kootenay River below Brilliant Dam and confluence areas of the tributaries was undertaken to identify any mainstem spawning area used by adult rainbow trout.

2.5.3 SPAWNING ESCAPEMENT ESTIMATES

The size of the rainbow trout spawning run in Norns Creek during 1983 was estimated using tagging and recapture data from both the fish trapping operation and backpack electrofishing surveys. Estimates of kokanee escapement into the Columbia River tributaries were based on visual enumerations. Two observers simultaneously walked the stream banks and enumerated the kokanee which generally were readily visible in the clear, shallow waters. These counts were then averaged and a range obtained. Counts were conducted on Norns Creek on three occasions during the spawning period. The other tributaries were surveyed twice to determine any use by kokanee for spawning. Historical escapement estimates for the period 1976 to 1979 that were obtained using similar methods were provided by the B.C. Fish and Wildlife Branch (P. Stent, pers. comm.).

2.5.4 FISH MARKING

Fish captured during the study were tagged to provide information on fish movements within the study area. Fish in good physical condition at the time of capture and exceeding 200 mm in length were marked with Floy FD68B anchor tags labelled with "RLL" followed by a five-digit number. Each tag was inserted into the dorsal musculature and through the pterygiophores, near the anterior portion of the dorsal fin. Tagged fish were released near their

point of capture. Information on angler recapture of the tagged fish was obtained from the B.C. Fish and Wildlife Branch regional office at Nelson.

2.5.5 FISH LIFE HISTORY DATA

2.5.5.1 Collection Phase

Pertinent life history data were collected from all fish species captured in the study area; however, emphasis was placed on sport fish species. Fork length to the nearest millimetre was recorded and weight determined on either a Chatillon Model 1038B spring scale (0 to 5000 g) or a Hanson Dietary scale (0 to 500 g). Sex and maturity were determined by dissection, external examination, or, during spawning seasons, release of sexual products. Scales for age determination were collected from the area immediately below the anterior insertion of the dorsal fin on the left side of the fish. They were then placed in envelopes for later processing. For an alternative method of aging, the left pectoral fin was removed from selected specimens and stored along with the scales. Otoliths were dissected from selected individuals and stored dry. Stomach contents of sacrificed fish were either examined cursorily in the field or the entire stomach was removed and stored in a 10% formalin solution for later analysis. All life history data were entered on fish data sheets for subsequent computer tabulation and analysis.

2.5.5.2 Analysis Phase

Fish aging was accomplished by mounting fish scales between glass microscope slides and then viewing with a 3M Model SRC816 microfiche reader or a binocular dissecting microscope. Otoliths were cleared in 2% KOH and aged using a binocular dissecting microscope. Fin rays were sectioned with a jewellers' saw, mounted on a microscope slide and aged using the dissecting microscope.

In this study, as in the previous Murphy Creek fisheries studies, kokanee were assigned ages according to the "freshwater method" (i.e., age corresponds to the number of annuli). However, in order to avoid confusion resulting from seasonal sampling, fish ages were adjusted to correspond to the calendar year (e.g., a fish caught in the spring prior to annulus formation was aged as the

number of annuli plus one). Kokanee scales which exhibited obvious resorption were not used in life history analyses. Ages were entered on the data sheets, and the information was then entered into the B.C. Hydro computer for sorting and analyses.

Preserved stomachs were evacuated after determination of fullness (after Thompson 1959). The organisms present were then identified and percentage composition calculated.

3.0 RESULTS AND DISCUSSION

3.1 WATER QUALITY

The following discussion on water quality in the Columbia and Kootenay rivers within the study area is based on the results of a limited sampling program (i.e., one sampling date in each of four seasons). As such, this discussion represents a preliminary description of the water quality in the study area.

3.1.1 CHEMICAL

The results of analyses of water quality samples from the Columbia and Kootenay rivers within the study area are presented in Table 3.1. Both the rivers are moderately alkaline (pH 7.8-8.0 laboratory measurement) and have low concentrations of suspended solids (less than 1 to 24 mg/L). The Kootenay River exhibited slightly higher levels of total dissolved solids and conductivity in comparison to the Columbia River near the Hugh Keenleyside Dam. Total phosphate levels were low in both rivers, with the values consistently being below the detection limit of 0.01 mg/L P. Dissolved nitrate/nitrite nitrogen levels were quite variable in both systems, ranging from 0.02 to 0.13 mg/L N. Total Kjeldahl nitrogen showed a similar variability, ranging from 0.02 to 0.19 mg/L N. Total organic carbon levels were highest in the Kootenay River and at the downstream site (Birchbank) on the Columbia River in comparison to the site near the Hugh Keenleyside Dam, likely reflecting the input of domestic sewage effluents in the Kootenay River (i.e., Nelson) and in the Columbia River (i.e., Castlegar) and the input of industrial effluent to the Columbia River by Westar Timber Ltd. upstream of Castlegar.

Seasonal variation in water quality also was noted for a number of parameters. Conductivity, total dissolved solids, and total organic carbon were highest during February 1983 and lowest during September 1982. Dissolved nitrate/nitrite was highest at all three sites during February. Total Kjeldahl nitrogen was highest in May at each of the sites, and lowest in July.

Comparison of water quality results from the present study with those obtained by the B.C. Government between 1973 and 1979 (IEC 1981; B.C.

Table 3.1. Water quality analyses - Columbia River and Kootenay River, 1982 and 1983.

Parameter	Columbia River 300 m Below Keenleyside Dam				Columbia River At Birchbank				Kootenay River Below Brilliant Dam			
	1982		1983		1982		1983		1982		1983	
	26 July	3 Sept	10 Feb	31 May[a]	26 July	3 Sept	10 Feb	31 May[a]	26 July	3 Sept	10 Feb	31 May[a]
PH	7.8	7.8	8.0	7.9	7.8	7.8	7.9	ND	7.8	7.8	8.0	7.8
Conductivity (µS/cm)	88	81	115	92	104	85	128	ND	96	91	130	90
Total suspended solids (mg/L)	3	L1[b]	L1	ND[c]	2	1	L1	ND	2	1	L1	24
Total dissolved solids (mg/L)	62	55	78	ND	71	56	87	ND	72	66	92	83
Total PO_4 (mg/L)	L0.01	L0.01	L0.01	L0.01	L0.01	L0.01	L0.01	ND	L0.01	L0.01	L0.01	L0.01
Total dissolved PO_4 (mg/L)	L0.01	L0.01	L0.01	L0.01	L0.01	L0.01	L0.01	ND	L0.01	L0.01	L0.01	L0.01
Total particulate PO_4 (mg/L)	L0.01	L0.01	L0.01	L0.01	L0.01	L0.01	L0.01	ND	L0.01	L0.01	L0.01	L0.01
Dissolved ortho-PO_4 (mg/L)	L0.01	L0.01	L0.01	L0.01	L0.01	L0.01	L0.01	ND	L0.01	L0.01	L0.01	L0.01
Dissolved NO_3/NO_2 (mg/L N)	0.03	0.11	0.13	0.09	0.03	0.08	0.12	ND	0.05	0.02	0.13	0.06
Total Kjeldahl N(mg/L N)	0.02	0.10	0.06	0.13	0.04	0.12	0.13	ND	0.04	0.15	0.06	0.19
Ammonia N (mg/L N)	L0.01	0.008	0.009	ND	L0.01	0.021	0.015	ND	L0.01	0.013	0.010	ND
Organic N (mg/L N)	0.02	0.09	0.05	ND	0.04	0.10	0.11	ND	0.04	0.14	0.05	ND
Silica (mg/L)	4.4	1.5	4.5	4.9	4.7	1.7	3.1	ND	4.4	2.4	3.8	5.6
Total organic carbon (mg/L)	8.1	2.6	12	4.0	9.2	3.8	13	ND	8.8	3.0	14	5.9

[a] Samples collected by B.C. Hydro staff as part of the 1983 detailed water quality study of Columbia River.

[b] L = Less than

[c] ND = No data

Ministry of Environment 1979) indicates that the present water quality is within the ranges of values of the previous studies.

3.1.2 DISSOLVED GAS LEVELS

The Columbia River below the Hugh Keenleyside Dam has been identified as having the highest total dissolved gas (TDG) concentrations of the 35 major rivers or lakes examined in British Columbia (Clark 1977). The B.C. Pollution Control Branch measured TDG levels of up to 144% saturation on 17 August 1976. The deleterious effects of high total dissolved gas levels on fish have been well documented (Weitkamp and Katz 1980; Fickeisen and Montgomery 1978; Ebel et al. 1975) and potential effects of high TDG levels in the Columbia River were described in Ash et al. (1981).

In an attempt to better understand the major factors affecting the concentrations of TDG in the Columbia River and the potential effects on the aquatic biota, the dissolved gas concentrations were measured at four sites (Hugh Keenleyside Dam forebay, the Columbia River 300 m downstream of the dam and at Birchbank, and the Kootenay River below the Brilliant Dam) during the four sampling periods. Total dissolved gas concentrations were lowest in Lower Arrow Lake (Hugh Keenleyside Dam forebay), and were highest immediately below the Hugh Keenleyside Dam (Table 3.2; Figure 3.1). TDG levels generally decreased between the dam and Birchbank as a result of gas dissipation, and dilution by flows with lower TDG levels from the Kootenay River. The only exception noted was on 28 April 1983, when the TDG concentrations in the Columbia River increased from 109.3% saturation at the site near the Hugh Keenleyside Dam, to 110.6% saturation at Birchbank. At that time, the TDG concentrations in the Kootenay River (i.e., 114.8% saturation) was higher than in the Columbia River, and flows were similar (1044 m^3/s and 917 m^3/s in the Columbia and Kootenay rivers, respectively).

The highest TDG levels were recorded on 20 July just below the Hugh Keenleyside Dam (Table 3.2). At that time, the total dissolved gas concentration was 124% saturation, with the oxygen and nitrogen/argon concentration being 111.2% and 127.1% saturation, respectively. The TDG levels were substantially higher at this site during periods of discharge through the

Table 3.2. Dissolved gas measurements from the Columbia and Kootenay rivers in the vicinity of Castlegar, July 1982 to April 1983.

Site	Date	Discharge (m^3/s)	Method of Discharge[a]	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Gas Percent Saturation		
						Oxygen (%)	Nitrogen and Argon (%)	Total (%)
Columbia R								
Forebay of	20 July	na	na	18.0	9.9	109.6	101.5	103.3
Hugh Keenleyside	3 Sept.	na	na	18.0	9.4	104.3	108.3	107.5
Dam.	11 Feb.	na	na	4.0	11.7	93.2	101.6	99.7
	26 April	na	na	6.0	12.1	101.8	104.7	104.0
300 m downstream	20 July	1860	S	16.0	10.6	111.2	127.1	124.0
of Hugh	3 Sept.	1689	S	16.0	11.2	117.4	119.9	119.7
Keenleyside Dam.	10 Feb.	1423	S	4.0	14.4	113.3	122.3	120.3
	29 April	1044	P	7.5	12.0	105.5	110.3	109.3
At Birchbank.	20 July	3840[b]	-[c]	15.5	10.8	112.8	123.2	121.2
	4 Sept.	2193[b]	-	13.0	11.0	121.5	116.7	117.8
	10 Feb.	2386[b]	-	4.5	14.0	111.6	116.3	115.2
	28 April	1960[b]	-	9.0	12.3	111.6	110.4	110.6
Kootenay R								
Below Brilliant	20 July	1979	T,S	15.5	10.8	105.7	117.0	114.9
Dam.	3 Sept.	504	S	18.0	9.0	99.7	105.7	104.5
	10 Feb.	963	T,S	4.0	13.5	106.1	112.2	110.8
	28 April	917	T,S	7.5	13.0	113.5	115.2	114.8

[a] P = through low-level ports
T = through turbines
S = over spillway/sluiceway
na = not applicable

[b] includes discharge from Kootenay River

[c] combination of methods from Hugh Keenleyside and Brilliant dams.

Date	Hugh Keenleyside Dam Discharge (m^3/s)	Method of Discharge
20 July	1860	S (sluiceway)
3,4 Sept.	1689	S "
10 Feb.	1423	S "
28,29 April	1044	P (port)

Date	Brilliant Dam Discharge (m^3/s)	Method of Discharge
20 July	1979	T,S (turbine, sluice.)
3 Sept.	504	T (turbine)
10 Feb.	963	T,S (turbine, sluice.)
28 April	917	T,S " "

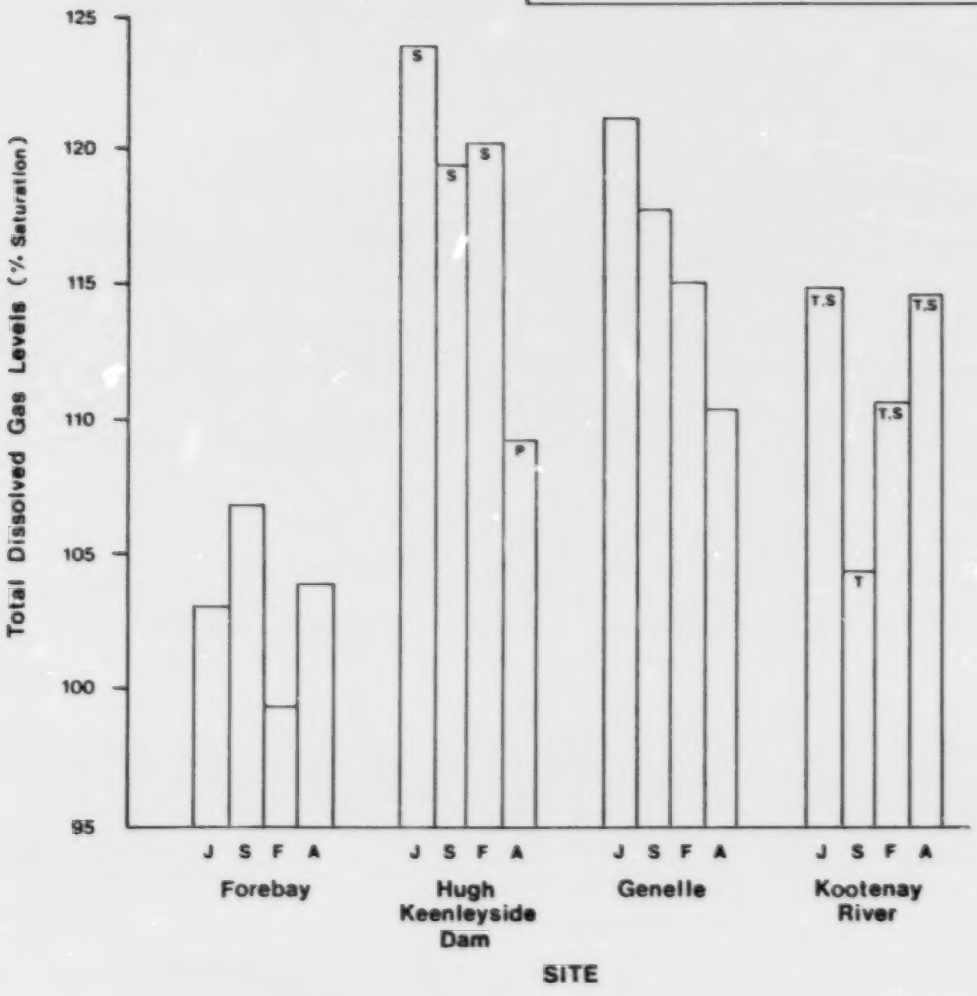


Figure 3.1. Total dissolved gas level (percentages) for four sites in the Columbia and Kootenay rivers from July 1982 to April 1983.

sluiceway (119.7 - 124.0% saturation), than during periods of discharge through the low-level ports (109.3%) at the Hugh Keenleyside Dam. These data support the contention that the high TDG concentrations in the Columbia River in the study area occur primarily when water at the Hugh Keenleyside Dam is discharged through the sluiceway (Ash et al. 1981). The unique design of the underwater concrete energy dissipator below the sluiceway, which causes the water and entrapped air bubbles to plunge to depths of up to 40 m and much of the water to be redirected back towards the plunging water, apparently contributes to the high TDG levels below this installation.

In order to identify any differences in TDG levels across the river channel, measurements were taken near the surface at three points across the channel at the site located 300 m below the Hugh Keenleyside Dam. The TDG concentrations were lower near the north bank of the river on both occasions (10 February and 29 April) in comparison with the other two sites on the transects (Table 3.3). This may be due to an eddy located along the north bank a short distance upstream; the longer residence time of water in the eddy may result in more gas dissipation than would occur from water in the main channel area.

In order to assess the significance of dissolved gas supersaturation on the fish in the Columbia River, all fish captured were examined for external signs of gas bubble disease. More specifically, this included examining the eyes, gill arches, pectoral and pelvic fins, dorsal fin, anal fin, caudal fin and the lateral line for the presence of gas bubbles. Of the 730 fish of 14 species captured and examined, only 16 exhibited the symptoms of gas bubble disease (Table 3.4). With the exception of one largescale sucker taken in September, all fish exhibiting symptoms of gas bubble disease were taken only in July, a period when TDG concentrations were at 124% saturation immediately below the Hugh Keenleyside Dam (Table 3.2). Of the 15 fish exhibiting gas bubble disease symptoms in July 1982, 12 were largescale suckers (out of 50 largescale suckers examined), two were rainbow trout (out of four examined), and one was a northern squawfish (out of 26 examined). Although some of the individuals had numerous cutaneous bubbles between the rays of the fins, no sign of exophthalmia, or "pop eye", was noted in any of the fish. Although exophthalmia is

Table 3.3. Dissolved gas measurements from a channel transect, located approximately 300 m below Hugh Keenleyside Dam, for 10 February and 29 April, 1983.

Date	Location[a]	Dissolved Oxygen (mg/L)	Dissolved Gas Percent Saturation		
			Oxygen %	Nitrogen and Argon %	Total %
10 Feb.	1/4 distance	14.6	115.0	121.0	119.6
	mid-channel	14.4	113.3	122.3	120.3
	3/4 distance	14.3	112.5	122.8	120.5
29 April	1/4 distance	11.9	104.2	109.0	108.0
	mid-channel	12.0	105.5	110.3	109.3
	3/4 distance	12.1	106.0	110.1	109.3

[a]Position from north bank.

Table 3.4. Affected area of body for fish displaying gas bubble disease during sample periods in July and August/September 1982 and April 1983.

Species	Locations Captured	Date Captured	Affected Area							
			Eyes	Gill Arches and/or Operculum	Pectoral Fins	Pelvic Fins	Dorsal Fin	Caudal Fin	Anal Fin	Lateral Line
Rainbow trout	ES-21	15 July		moderate[a]	light[a]		heavy[a]		heavy	
Rainbow trout	ES-29	15 July			moderate	light				
Largescale sucker	ES-21	15 July				light	heavy	heavy		
Largescale sucker	ES-21	15 July		moderate			heavy	heavy	heavy	
Largescale sucker	ES-20	15 July				light	light	light		
Largescale sucker	ES-30	15 July					light	light		
Largescale sucker	ES-21	17 July					light			
Largescale sucker	ES-21	17 July			heavy	heavy	heavy	heavy	heavy	moderate
Largescale sucker	ES-21	17 July		light			moderate	moderate	moderate	
Largescale sucker	ES-21	17 July						light		
Largescale sucker	ES-19	18 July							light	
Largescale sucker	ES-19	18 July		light	moderate	moderate	moderate	moderate	moderate	
Largescale sucker	ES-18	18 July					heavy			
Largescale sucker	ES-26	19 July					moderate			
Largescale sucker	ES-30	01 Sept			light	light	moderate			
Northern squawfish	ES-29	15 July					light			

[a] degree of affliction:

light = 5 or less small bubbles.

moderate = 6-10 small bubbles, or 1-2 large bubbles.

heavy = more than 10 small bubbles, or 3 or more large bubbles.

commonly associated with gas bubble disease, Meekin and Turner (1974) reported it in less than 5% of dead juvenile chinook salmon suffering from gas bubble disease.

Mountain whitefish have been shown to be one of the fish most susceptible to gas bubble disease mortality. Fickeisen and Montgomery (1978) reported that the LE50 (i.e., the lethal exposure time for 50% of the subjects) was 14 h at a TDG level of 124% saturation and that all the mountain whitefish were dead after 48 h. Blahm et al. (1976) reported an LE50 for mountain whitefish of 23.5 h at 130% N_2 saturation. The LE50 for rainbow trout at this same N_2 concentration (130%) was 47.0 h indicating that rainbow trout are slightly more tolerant of high dissolved gas levels than are mountain whitefish. The LE50 for these two species held in water at 120% nitrogen saturation was 50.5 h and 141.5 h for mountain whitefish and rainbow trout, respectively.

Coarse fish species generally appear to be more tolerant of high dissolved gas levels than are salmonids. Fickeisen and Montgomery (1978) reported the LE50 for largescale suckers was 67 h at 124% saturation. Bentley et al. (1976) noted an LE50 of 20 h for northern squawfish held at a TDG level of 126% saturation.

The cause of death from gas bubble disease has generally been attributed to anoxia resulting from stasis of the blood (Weitkamp and Katz 1980). This can occur when gas bubbles fill the bulbus of the heart, preventing the movement of blood, or as a result of emboli forming in the gills or in the brain, causing blood stasis. Although TDG levels in the Columbia River in July 1982 were high enough to cause severe symptoms of gas bubble disease in most species of fish, no dead fish were noted. This may be due to the fish remaining in shallow water for only a short period of time, and then moving into deeper water to take advantage of hydrostatic compensation, thereby limiting the effects of supersaturation. With each metre of depth, the additional pressure increases the solubility of dissolved gases sufficiently to compensate for approximately 10% of saturation (Weitkamp and Katz 1980). The differences in the proportion of fish exhibiting symptoms of gas bubble disease among the species in the study may be related to a combination of factors such as the extent of time that the fish spend in the shallows feeding, the location of its preferred habitat

within the study area, and the tolerance of the species to high dissolved gas levels.

3.2 MYSID SAMPLING

3.2.1 SEASONAL RECRUITMENT

Mysis relicta was introduced into Upper Arrow Lake in 1967 (B.C. Fish and Wildlife Branch N.D.) and again in the early 1970's (B. Lindsay, B.C. Fish and Wildlife Branch, pers. comm.) to provide a food source for rainbow trout and kokanee in the reservoir. To date, no comprehensive studies have been conducted to document mysid abundance in the Arrow Lakes Reservoir, or their effect on fish production in the system.

To assess the seasonal differences in recruitment of mysids into the study area, the Columbia River below the Hugh Keenleyside Dam was sampled during summer and fall of 1982, and winter and spring of 1983. In deep lakes, mysids display a diurnal migration pattern in which they move from deep waters at dusk to feed in the metalimnion; subsequently, they return to the bottom by pre-dawn (Mundie 1959; Beeton 1960; Gosho 1975; Morgan et al. 1978; Mauchline 1980). Since they are poor swimmers and are easily transported by currents (Holmguist 1959 cited in Gosho 1975; Ricker 1959), it was assumed that it is during the period when they are in the metalimnion that they become entrained at the Hugh Keenleyside Dam and pass through the ports or sluiceway into the Columbia River. To test this assumption, daytime sampling was conducted on 2 September 1982 at Site M1, located below the Hugh Keenleyside Dam (Table 3.5). Only eight mysids were captured in nine net sets, with seven of the mysids being taken at 1000 h. In contrast, seven to 206 mysids were captured per net during nighttime sets on 28-29 August 1982, indicating that daytime densities are insignificant in comparison to nighttime densities.

During nighttime sampling at Site M1 below the Hugh Keenleyside Dam, mysid densities generally were highest near the bottom of the water column (Table 3.6), indicating that the mysids may be sounding in response to the current. The mean density of mysids within the water column during the nighttime sampling periods from dusk to 0200 h generally was highest during the 2400 h (midnight) sampling period, irrespective of season. As a consequence,

Table 3.5. Numbers and density of Mysis relicta collected in drift nets (all sets 15 min) during daytime sets in the Columbia River downstream from Hugh Keenleyside Dam (Site M1), 2 September 1982.

Net Position	Time of Day (h)								
	1000			1400			1800		
	No. Collected (N)	Estimated Volume Sampled (m^3)	Density (N/m^3)	No. Collected (N)	Estimated Volume Sampled (m^3)	Density (N/m^3)	No. Collected (N)	Estimated Volume Sampled (m^3)	Density (N/m^3)
Top	5	84.2	0.06	0	86.7	0	0	89.1	0
Middle	1	65.8	0.02	0	67.9	0	0	69.8	0
Bottom	1	41.6	0.02	1	42.6	0.02	0	43.6	0

Table 3.6. Numbers and density of Mysis relicta collected in drift nets (all sets 15 min) during nighttime sets in the Columbia River downstream from Hugh Keenleyside Dam (Site M1), 1982 and 1983.

Date	Net Position	Time of Day (h)														
		1800			2000			2200			2400			0200		
		No. Collected (N)	Estimated Volume Sampled (m^3)	Density (N/m^3)	No. Collected (N)	Estimated Volume Sampled (m^3)	Density (N/m^3)	No. Collected (N)	Estimated Volume Sampled (m^3)	Density (N/m^3)	No. Collected (N)	Estimated Volume Sampled (m^3)	Density (N/m^3)	No. Collected (N)	Estimated Volume Sampled (m^3)	Density (N/m^3)
19-20 July 1982	Top	-	-	-	-	-	-	91	140.9	0.65	210	129.6	1.62	177	135.3	1.31
	Middle	-	-	-	-	-	-	73	111.6	0.65	192	102.5	1.87	161	107.1	1.50
	Bottom	-	-	-	-	-	-	60	64.6	0.93	176	59.9	2.94	252	62.4	4.04
Totals/Mean Density								**224**	**317.1**	**0.71**	**578**	**292.0**	**1.98**	**590**	**304.8**	**1.94**
28-29 Aug. 1982	Top	-	-	-	7	84.2	0.08	58	86.7	0.67	39	89.1	0.44	84	86.7	0.97
	Middle	-	-	-	76	65.8	1.16	78	67.9	1.15	69	69.8	1.00	71	67.9	1.04
	Bottom	-	-	-	20	41.6	0.48	30	42.6	0.70	206	43.6	4.72	41	42.6	0.96
Totals/Mean Density					**103**	**191.6**	**0.54**	**166**	**197.2**	**0.84**	**314**	**202.5**	**1.55**	**196**	**197.2**	**0.99**
9-10 Feb. 1983	Top	1	56.7	0.02	5	53.5	0.09	7	89.1	0.08	4	66.8	0.06	6	68.0	0.09
	Middle	1	43.6	0.02	10	41.0	0.24	2	69.8	0.03	12	51.8	0.23	7	52.8	0.13
	Bottom	1	29.2	0.03	2	45.4	0.04	2	37.3	0.05	11	34.5	0.32	8	35.0	0.23
Totals/Mean Density		**3**	**129.5**	**0.02**	**17**	**139.9**	**0.12**	**11**	**196.2**	**0.06**	**27**	**153.1**	**0.18**	**21**	**155.8**	**0.13**
23-24 Apr. 1983	Top	-	-	-	0	27.5	0	0	25.1	0	0	23.5	0	0	25.1	0
	Middle	-	-	-	0	20.1	0	0	17.8	0	0	16.8	0	2	17.8	0.11
	Bottom	-	-	-	0	9.7	0	0	17.3	0	2	16.8	0.12	1	16.2	0.06
Totals/Mean Density					**0**	**57.3**	**0**	**0**	**60.2**	**0**	**2**	**57.1**	**0.04**	**3**	**59.1**	**0.05**

this sampling period appears most suitable for comparisons between seasons or sampling sites.

Densities of Mysis relicta at Site M1 were highest during the July sampling period (2400 h mean of 1.98 mysids/m^3; Q = 1860 m^3/s[a]) and lowest during the April sampling period (2400 h mean of 0.04 mysids/m^3; Q = 1044 m^3/s) (Table 3.6). Densities during the 2400 h sampling period in August (Q = 1869 m^3/s) and February (Q = 1423 m^3/s) were 1.55 and 0.18 mysids/m^3, respectively. Although mysid densities in the Columbia River are related to volume of discharge at the dam (i.e., r^2 = 0.81 for 2400 h sample), it is probable that the densities in the river are more directly related to mysid densities in Lower Arrow Lake. The seasonal differences observed, are likely primarily a reflection of mysid population dynamics within Lower Arrow Lake.

To assess the extent of cropping of mysids by fish in the upper reaches of the Columbia River, sampling was conducted at Site M2, located approximately 7 km below Site M1, during the August, February and April survey periods. Sampling at the second site was scheduled within one to two days of the sampling of the first site to reduce the chances of differences in environmental factors (e.g., weather conditions, changes in flow, etc.) which may influence mysid abundances and vertical distribution. However, since sampling at the two sites was not conducted concurrently, the results must be interpreted with caution.

The densities of mysids at the Site M2 (Table 3.7) were substantially lower than at the upper site during the August sampling period (i.e., 0.12/m^3 at Site M2 vs. 1.55/m^3 at Site M1) during the 2400 h sampling period), but were similar during both the February and April sampling periods. The low recruitment of mysids from Lower Arrow Lake during the latter two periods may have influenced the extent of cropping of the mysids by fish, or may have made differences between the two sites difficult to detect.

---

[a]Discharge (Q) at the Hugh Keenleyside Dam.

Table 3.7. Numbers and density of Mysis relicta collected in drift nets (all sets 15 min) during nighttime sets in the Columbia River near the Castlegar-Robson ferry (Site M2), 1982 and 1983.

Date	Net Position	Time of Day (h) 1800			2000			2200			2400			0200		
		No. Collected (N)	Estimated Volume Sampled (m^3)	Density (N/m^3)	No. Collected (N)	Estimated Volume Sampled (m^3)	Density (N/m^3)	No. Collected (N)	Estimated Volume Sampled (m^3)	Density (N/m^3)	No. Collected (N)	Estimated Volume Sampled (m^3)	Density (N/m^3)	No. Collected (N)	Estimated Volume Sampled (m^3)	Density (N/m^3)
26-27 Aug. 1982	Top	-	-	-	-	-	-	8	87.5	0.09	9	87.5	0.10	27	87.5	0.31
	Middle	-	-	-	-	-	-	1	88.4	0.01	7	88.4	0.08	18	88.4	0.20
	Bottom	-	-	-	-	-	-	9	80.8	0.11	15	80.8	0.19	29	80.8	0.36
Totals/Mean Density								18	256.7	0.07	31	256.7	0.12	74	256.7	0.29
10-11 Feb. 1983	Top	0	71.3	0	0	71.3	0	0	71.3	0	0	71.3	0	3	71.3	0.04
	Middle	0	71.8	0	1	71.8	0.01	2	71.8	0.03	13	71.8	0.18	15	71.8	0.21
	Bottom	8	74.5	0.11	3	72.1	0.04	27	72.1	0.37	22	69.7	0.32	19	72.1	0.26
Totals/Mean Density		8	217.6	0.04	4	215.2	0.02	29	215.2	0.13	35	212.8	0.16	37	215.2	0.17
21-22 Apr. 1983	Top	-	-	-	0	44.6	0	0	45.4	0	1	44.6	0.02	0	43.7	0
	Middle	-	-	-	0	30.8	0	1	30.8	0.03	1	30.8	0.03	2	30.8	0.06
	Bottom	-	-	-	1	16.2	0.06	0	16.2	0	1	16.2	0.06	1	16.2	0.06
Totals/Mean Density					1	91.6	0.01	1	92.4	0.01	3	91.6	0.03	3	90.7	0.03

3.2.2 MYSID LIFE HISTORY

The length of time for Mysis relicta to reach sexual maturity varies greatly from system to system, with the differences possibly being related to energetic considerations (i.e., depth and productivity) (Morgan 1980,1981), temperature differences (Lasenby and Langford 1972; Berrill and Lasenby 1983), or possibly a combination of both. Lasenby and Langford (1972) suggested that at higher latitudes, M. relicta require two years to reach maturity as opposed to one year in temperate zones. Morgan (1980,1981), however, reported that in Lake Tahoe (California-Nevada), M. relicta take four years to reach sexual maturity, while in Emerald Bay, an isolated (for Mysis) embayment of Lake Tahoe, they require only one to two years. This he attributed to differences in trophic status, and energetic considerations. Berrill and Lasenby (1983), however, concluded that where food is not limiting, mysids living in water of at least 8°C during the summer and autumn of their first year should reach sexual maturity quickly enough to complete their life cycle in one year.

In the Columbia River, sampling frequency was too low to allow the determination of the age at which the mysids in Arrow Lakes Reservoir first reach maturity. However, based on the temperature model proposed by Berrill and Lasenby (1983), the mysids likely reach maturity within one year, since the surface water of Arrow Lakes Reservoir warms to temperatures above 8°C during the summer and fall (B.C. Research 1977; B.C. Ministry of Environment, EQUIS Site No. 0200524).

In the Columbia River, eggs and brood were present in the marsupium or brood pouch only during the February sample (Table 3.8). Of the 24 female mysids collected during February of 1983 that contained eggs or brood in the marsupium, four contained eggs (mean no. eggs/female was 9.25; range = 5-14), 17 contained Stage 2 larvae (mean no. larvae/female was 12.6; range = 7-21), and three contained Stage 3 larvae (mean no. larvae/female was 11.7; range = 6-16) (Table 3.8). Since most of the larvae of mysids in the Columbia River had developed to Stage 2, with some having developed to Stage 3, by 9-11 February, it appears that the female mysids in Lower Arrow Lake release their eggs into the brood pouch during the period October to February. The larvae likely are released from the brood pouch during the period February to

Table 3.8. Number and size of eggs or brood carried per female mysid collected from the Columbia River, February 1983.

Date	Female Total Length (mm)	Egg/Larvae Numbers and Size (mm)								
		Stage 1 – Egg			Stage 2 – Eyeless Larvae			Stage 3 – Eyed Larvae		
		N	$\bar{x}$	Range	N	$\bar{x}$	Range	N	$\bar{x}$	Range
9 Feb	17.0							6	4.0	3.0-6.3
	16.5				12	1.6	1.0-1.9			
	18.0				11	2.4	2.2-2.6			
	17.3				11	2.2	2.1-2.4			
	14.1	6	0.9	0.8-0.9						
	17.6				9	2.1	2.0-2.3			
	16.0				14	2.3	2.2-2.4			
	18.0	14	0.9	0.8-0.9						
	19.2	12	0.9	0.9-1.0						
10 Feb	14.8				12	2.2	2.1-2.2			
	17.7							16	2.2	2.0-2.4
	16.6				12	2.1	2.0-2.1			
	15.5							13	2.6	2.5-2.9
	16.5				11	2.1	2.1-2.2			
	16.5				17	2.2	2.1-2.2			
11 Feb	16.5				13	2.1	2.0-2.1			
	19.5				21	2.2	2.1-2.3			
	15.0				14	2.3	1.2-3.0			
	16.0	5	1.0	0.9-0.1						
	20.7				19	2.3	2.1-2.5			
	17.0				9	2.2	2.1-2.3			
	17.6				7	2.2	2.1-2.3			
	17.2				9	2.2	2.1-2.4			
	18.9				16	2.1	1.9-2.3			

June. Since only 13 juvenile mysids were collected during the April sampling period, it was not possible to determine if the majority of the females had released their brood at that time. In a study of mysids in Stoney Lake, Ontario, Lasenby and Langford (1972) observed that female mysids lay their eggs in the brood pouch in December, and that the embryos took five months to develop in the marsupium. The immature mysids were released from the brood chamber in May, at a length of about 4 mm.

Of the 24 mysids with eggs or brood collected in the Columbia River, the mean number of eggs/brood per female was 12.0 $\pm$ 0.83 (SE) (range = 5-21). This is similar to the mean of 12 eggs/female (range = 5-22; n = 75) for mysids in Char Lake, N.W.T., and 12 eggs/female (range = 10-14; n = 22) in Stoney Lake, Ontario (Lasenby and Langford 1972).

The mean length of the mysids collected from the Columbia River generally increased from the July sample period through to the February sample period (Table 3.9), with the mean length of males increasing from 12.2 $\pm$ 0.72 (SE) mm to 15.0 $\pm$ 0.20 (SE) mm. Mean length of females increased from 16.0 $\pm$ 0.43 (SE) mm to 17.4 $\pm$ 0.16 (SE) mm, although in September the mean length was only 13.1 $\pm$ 0.85 (SE) mm. The decrease in September may be attributable to the small sample sizes in July and September. Unsexed juveniles showed the greatest increase in mean length, from 8.4 $\pm$ 0.26 (SE) mm in July to 14.7 $\pm$ 0.40 (SE) mm in February. The large increase in February reflects the high numbers of large mysids that did not carry a brood sac or show the male characteristics. These may represent females that had their brood pouch torn away by the turbulence during passage through the ports at the Hugh Keenleyside Dam. Since the biomass of a mysid is correlated to length, the mean biomass/mysids was highest during February (9.299 mg/mysid), and lowest in the sample collected in April (0.595 mg/mysid) when only unsexed juveniles were collected (Table 3.9).

3.2.3 UTILIZATION BY FISH

The mysids that become entrained at the Hugh Keenleyside Dam constitute an important food source for fish in the Columbia River within the study area. Lindsay (1976) noted that during a January to March creel survey in 1976,

Table 3.9. Mean length and biomass[a] of mysids preserved during each of the four sample periods, 1982 and 1983.

Date	Total Length (mm)												Biomass/Mysid mg dry weight		
	Males				Females				Unsexed Juveniles						
	N	$\bar{x}$	Range	SE	N	$\bar{x}$	Range	SE	N	$\bar{x}$	Range	SE	N	$\bar{x}$	SE
19-20 July	17	12.2	7.0-17.5	0.72	8	16.0	15.0-18.0	0.43	96	8.4	5.0-18.5	0.26	121	2.785	0.29
1-2 Sept	15	13.6	10.6-17.3	0.51	7	13.1	12.1-18.2	0.85	179	9.25	5.1-12.7	0.11	201	2.450	0.12
10-11 Feb	56	15.0	11.5-20.0	0.20	75	17.4	14.1-21.0	0.16	56	14.7	4.5-19.6	0.40	187	9.299	0.25
21-23 April	0	-	-	-	0	-	-	-	13	6.0	4.5-8.2	0.30	13	0.595	0.09

[a]individual mysid biomass was calculated from the length-weight relationship presented by Lasenby and Langford (1972).

kokanee in the section of the Columbia River below the Hugh Keenleyside Dam were feeding primarily on mysids. Of the 42 kokanee examined, mysids contributed 99.91% of the contents by volume, and zooplankton contributed 0.09%. During the present study, stomach contents of 182 fish of seven different species were evaluated to assess the importance of M. relicta as a fish food item within the study area (Appendix B, Table B-1). Of the 35 kokanee examined, mysids contributed 79.7% by volume to the food present. Mysids also were important in the diet of rainbow trout (54.2% of food by volume; n = 10), and mountain whitefish (33.4% of food by volume; n = 70). Mysids contributed only a minor component (3.8%; n = 51) to the diet of redside shiners, and were not detected in the stomachs of northern squawfish (n = 6), peamouth (n = 9), or walleye (n = 1).

Kokanee fed primarily on mysids during each of the three fish sampling periods, with the percentage contribution ranging from 68.6% to 94.4% (Appendix B; Table B-1). Mountain whitefish fed heavily on mysids during July and August of 1982, but not during April of 1983. The reason for the absence of mysids in the diet of mountain whitefish in April is not clear since the mysids were present in the diet of kokanee taken during the same period. However, during April mysids were present only in low numbers in the Columbia River, and most were small immature individuals. The kokanee likely are better adapted to feeding on the smaller mysids than are the mountain whitefish (i.e., kokanee are normally planktonic feeders).

The presence of an abundant food supply (i.e., mysids, zooplankton, etc.) entering the Columbia River from Arrow Lakes Reservoir throughout most of the year likely is responsible for the relatively high fish productivity within the study area. This, in turn, is reflected in the high quality sportfishery that is present on this section of the Columbia River.

3.3 BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates are an integral component of the stream ecosystem, representing an intermediary step in the aquatic food chain between the primary producers and fish. In the present study, benthic macroinvertebrates along the margins of the Columbia River were sampled to provide

baseline data to allow an assessment of species composition and seasonal abundance. Granular substrates (gravel/cobble) at three sites were sampled with the Hess sampler; silt/sand substrates at two sites were sampled with the Ekman grab. Several parameters have been used in this report to describe the macrobenthic fauna; these include composition and abundance of organisms, number of taxa collected, and the Shannon-Weaver diversity index ($\bar{d}$). Analysis of the benthic invertebrate data collected during the present study has been conducted separately for the two habitat types sampled. A summary of abundance, number of taxa, and diversity of benthic invertebrates collected from the granular substrates (gravel/cobble) is presented in Table 3.10; species composition and abundance of the individual taxa are presented in Appendix C (Tables C-1 to C-3). A summary of abundance, number of taxa, and diversity of benthic invertebrates collected from sand/silt substrates is presented in Table 3.11; species composition and abundance of the individual taxa are presented in Appendix C (Tables C-4 and C-5).

At the sites with a granular substrate (i.e., erosional habitats), the number of organisms collected was highest during August 1982 mainly due to high numbers of Hydra (Table 3.10 and Appendix C, Tables C-1 to C-3). The number of organisms collected was lowest during the April 1983 sampling period at sites H1 and H3, and during July 1982 at Site H2. This seasonal pattern of maximum numbers of macroinvertebrates in the late summer and fall, and minimum numbers in the spring or early summer, is typical of most temperate rivers (Hynes 1970). The number of taxa collected was greatest in April 1983 at sites H1 and H2. At Site H3 the number of taxa were similar during each of the three sample periods. The diversity index, which uses a mathematical formula to describe in a single figure the number (or richness) of taxa and the distribution of individuals among the taxa, was highest during the April sampling period at all three sites (Table 3.10). Diversity in a benthic invertebrate community is greatest when the organisms are equally distributed among a high number of taxa, and the general theory is that an unstressed, healthy community has a higher diversity than a stressed community.

The collected fauna at the Hess sampling sites was dominated by Hydra, oligochaetes and chironomids (Orthocladiinae) (Appendix C, Tables C-1 to C-3).

Table 3.10. Summary of abundance, number of taxa and Shannon-Weaver diversity ($\bar{d}$) for Hess cylinder samples collected during 1982 and 1983.

	Abundance (mean no./m^2)	Number of Taxa[a]	Diversity[a] ($\bar{d}$)
Site H1			
20 July 1982	1 223	11	1.78
29 August 1982	12 687	12	1.16
29 April 1983	1 090	20	2.55
Site H2			
21 July 1982	1 670	8	0.84
30 August 1982	5 303	8	0.30
29 April 1983	1 907	27	3.70
Site H3			
20 July 1982	583	17	2.81
29 August 1982	2 527	17	1.68
28 April 1983	353	16	3.07

[a]based on three pooled samples.

Table 3.11. Summary of abundance, number of taxa and Shannon-Weaver diversity ($\bar{d}$) for Ekman grab samples collected during 1982 and 1983.

	Abundance (mean no./m^2)	Number of Taxa[a]	Diversity[a] ($\bar{d}$)
Site E1			
20 July 1982	13 218	12	1.14
29 August 1982	11 827	13	1.32
29 April 1983	7 763	17	2.83
Site E2			
20 July 1982	702	8	2.32
30 August 1982	1 864	8	1.57
28 April 1983	1 322	9	2.69

[a]based on three pooled samples.

Hydra were most abundant during the August 1982 sampling period at all three sites, contributing between 70% (Site H3) and 96% (Site H2) to the total number of organisms in the samples. At this time, Hydra decreased in abundance from Site H1 to H3, likely a reflection of higher food availability (zooplankton) near the dam. Hydra also were abundant in the July 1982 sample at Site H2, contributing approximately 81% to the total number of organisms. This taxa only made a minor contribution to the totals at the other sites (36% at Site H1 and 3% at Site H3) during July, and at all sites during the April 1983 sampling period (2 to 10% of total number of organisms).

At the two sites with a sand/silt substrate, the number of organisms collected was highest in July 1982 at Site E1, and during August 1982 at Site E2 (Table 3.11). Overall, the number of organisms collected was substantially greater during each survey period at Site E1 than at Site E2. Similarily, the number of taxa collected was consistently greater at Site E1, with the maximum number of taxa (17) being present during the April 1983 sampling period. Diversity was highest at both sites during April, and was lowest during July at Site E1, and during August at Site E2. The only sampling period which showed a major difference in diversity between the two sites was July 1982, with E2 having a higher diversity. The dominant taxa present in the Ekman grab samples (Appendix C, Tables C-4 and C-5) were similar to those in the Hess cylinder samples; these included Hydra, oligochaetes, and chironomids. At the Ekman grab sites, however, Chironomini, which favour slower water habitats with soft substrates, were the dominant group of chironomids (compared to Orthocladiinae at the granular substrate sites). Gastropods also generally were more abundant on the sedimentary substrates than on the granular substrates.

The extensive water level fluctuations that occur in the Columbia River as a result of variations in discharge, undoubtedly affect the benthic invertebrate communities in the river as well as the sampling of those communities. Since sampling for benthic invertebrates was conducted in shallow water areas (i.e., generally 30-40 cm depth at Hess sampling sites, and at depths of 1-2 m at the Ekman grab sampling sites), the water level at the time of sampling influenced the exact location sampled (i.e., at higher water levels the area sampled likely was dewatered during the previous periods of lower discharge).

The tailwater elevation at the Hugh Keenleyside Dam remained relatively stable between the July and August 1982 sampling periods (i.e., 24.930 m referred to assumed datum on 20 July, and 24.591 m on 29 August), with the tailwater levels during this period varying from a high of 26.845 m (4 August) to a low of 24.336 m (26 August) (Water Survey of Canada 1983). However, water levels prior to the July 1982 sampling period had been lowered to 22.726 m on 10 June 1982 and to the year low of 20.948 m on 22 February 1982. This indicates that the macroinvertebrates collected during the July and August sampling periods likely would have had to recolonize the area sampled since mid-June (i.e., the area sampled would have been dewatered in mid June). This likely accounts for the low number of taxa found during the July and August 1982 sampling periods in comparison to the number of taxa present during the April 1983 sampling period when water levels were low (i.e., the area sampled would not have been recently dewatered). The high numbers of organisms present in the August samples are attributable to large numbers of Hydra, an organism that can rapidly recolonize an area and quickly form large populations when conditions are favorable. Also, the late summer/autumn is generally the season when maximum numbers of benthic macroinvertebrates occur as new specimens hatch from eggs (Hynes 1970).

3.4 FISH RESOURCES

3.4.1 SEASONAL SPECIES COMPOSITION AND STATUS

During the present study, 18 species of fish were encountered in the study area (Table 3.12). Species composition was identical to the assemblage recorded in 1980-1981, with the exception that brook trout and cutthroat trout were not captured during the present study. Only one brook trout and one cutthroat were captured in the previous study; this indicated a limited population status for these species and suggested the individuals were strays from populations located outside the immediate study area.

Approximately 47 600 fish were captured or observed during the three fish sampling intervals of the present study (Table 3.13). Redside shiners and catostomid species contributed 76.3% and 8.1%, respectively to the total catch. In the 1980-1981 study, the catch was comprised of 78.4% redside shiners and 12% sucker species.

Table 3.12. Fish species encountered in the Columbia River and tributaries, 1982 and 1983.

Common Name	Species Code	Scientific Name
Kokanee	(K)	Oncorhynchus nerka (Walbaum)
Rainbow trout	(RT)	Salmo gairdneri Richardson
Bull trout[a]	(DV)	Salvelinus confluentus (Suckley)
Lake whitefish	(LW)	Coregonus clupeaformis (Mitchill)
Mountain whitefish	(MW)	Prosopium williamsoni (Girard)
Walleye	(YW)	Stizostedion vitreum vitreum (Mitchill)
Burbot	(LING)	Lota lota (Linnaeus)
Bridgelip sucker	(BLS)	Catostomus columbianus (Eigenmann and Eigenmann)
Longnose sucker	(LNS)	Catostomus catostomus (Forster)
Largescale sucker	(LSS)	Catostomus macrocheilus Girard
Carp	(CARP)	Cyprinus carpio Linnaeus
Northern squawfish	(NSF)	Ptychocheilus oregonensis (Richardson)
Peamouth	(PM)	Mylocheilus caurinus (Richardson)
Redside shiner	(RSS)	Richardsonius balteatus (Richardson)
Longnose dace	(LND)	Rhinichthys cataractae (Valenciennes)
Prickly sculpin	(PS)	Cottus asper Richardson
Shorthead sculpin	(STHS)	Cottus confusus Bailey and Bond
Torrent sculpin	(TS)	Cottus rhotheus (Smith)

Total number of species : 18

[a] Recently renamed from Dolly Varden - Salvelinus malma (Walbaum)

Table 3.13. Numbers of fish captured or observed by various sampling methods, and percentage composition of total catch (by species) in the Columbia River and selected tributaries[a], 1982 and 1983.

Species	Night Electrofishing	Backpack Electrofishing	Box Trap	Total No.	Total %
K	283	-	-	283	0.6
RT	99	85	15	199	0.4
DV	20	-	-	20	L 0.1[b]
MW	2 569	-	2	2 571	5.4
LW	1	-	-	1	L 0.1
YW	16	-	-	16	L 0.1
LING	49	-	-	49	0.1
Suckers[c]	3 644	-	-	3 644	7.7
BLS	1	-	-	1	L 0.1
LNS	24	-	-	24	L 0.1
LSS	179	-	-	179	0.4
CARP	4	-	-	4	L 0.1
NSF	619	-	-	619	1.3
PM	1 772	-	-	1 772	3.7
RSS	36 302	-	-	36 302	76.3
LND	-	1	-	1	L 0.1
PS	1 909	-	-	1 909	4.0
SHTS	-	3	-	3	L 0.1
TS	-	2	-	2	L 0.1
Totals	**47 491**	**91**	**17**	**47 599**	

[a] includes Norns, Champion, Murphy, China and Blueberry creeks.

[b] L = less than

[c] observed; not identified to species

Sportfish abundance in the total catch did not alter appreciably between the 1980-1981 and 1982-1983 studies. The differences occurring between the previous and present studies were a decrease in kokanee abundance by 0.1%, an increase in rainbow trout abundance by 0.3%, and an increase in mountain whitefish abundance by 0.7%. The relative abundance of the individual species within the sportfish catch showed more appreciable changes during this two year period. The total sportfish catch within the study area was 6177 fish in 1980-1981, and 3139 fish in 1982-1983. During these intervals, kokanee relative abundance in the catch decreased from 11.7% to 9.0%, rainbow trout increased from 2.2% to 6.4% and mountain whitefish decreased from 83.5% to 81.9% of the sportfish catch. Other species exhibiting a slight increase in relative abundance include bull trout (0.2% to 0.6%), and walleye (0.1% to 0.5%). Burbot relative abundance decreased slightly from 2.1% of the sportfish catch in 1980-1981 to 1.6% in 1982-1983.

Seasonal variation in night electrofishing catches is presented in Table 3.14. Catch per unit effort (CUE = no. fish/km) data for each electrofishing section are presented in Appendix D. Between the summer and fall of 1982, the most noteable changes were substantial increases in CUE for mountain whitefish, suckers, redside shiners and prickly sculpins. Substantial decreases in CUE occurred between fall (1982) and spring (1983) for mountain whitefish, suckers, cyprinids and sculpins; kokanee and rainbow trout CUE'S increased during this period.

The seasonal variation of rainbow trout CUE between the 1980-1981 and 1982-1983 catch is illustrated in Figure 3.2. Catch per unit effort values were higher for summer 1980 (i.e., CUE = 1.9) than for summer 1982 (i.e., CUE = 0.4). Similar values were recorded for fall 1980 (CUE = 0.1) and fall 1982 (CUE = 0.3). Catches of rainbow trout in spring 1983 (CUE = 4.0) were substantially higher than for spring 1981 (CUE = 0.4), but they were similar to spring 1980 (CUE = 4.4).

Catches of kokanee were substantially greater in summer 1980 (CUE = 26.6) than in summer 1982 (CUE = 1.9) (Figure 3.2). Fall kokanee catch was comparable between 1980 (CUE = 2.0) and 1982 (CUE = 2.2). The spring 1983 kokanee catch (CUE = 9.6) was intermediate between spring 1980 (CUE = 17.3) and spring 1981 (CUE = 0.2).

Table 3.14. Night electrofishing catch and *CUE* (No. fish per km) for all sample sections in the mainstem Columbia River, 1982 and 1983.

Period	Distance	Number[a] and *CUE*															Total Fish
	(km)	YW	K	RT	LW	DV	MW	Suckers[b]	LNS	LSS	BLS	NSF	LING	PS	PM	RBS	CARP	*CUE*
Summer																		
14-16 July	19.4	3	37	8	1	8	129	304	8	122	1	182	37	240	700	1 006	3	2 789
		0.2	1.9	0.4	0.05	0.4	6.6	15.7	0.4	6.3	0.05	9.4	1.9	12.4	36.1	51.9	0.2	143.8
Fall																		
27 Aug - 2 Sept	20.2	9	44	6		5	2 116	3 284	10	38		402	9	1 625	1 071	24 001	1	32 621
		0.4	2.2	0.3		0.2	104.8	162.6	0.5	1.9		19.9	0.4	80.4	53.0	1 188.2	0.05	1 614.9
Spring																		
15-18 April	21.0	4	202	85		7	324	56	6	19		35	3	44	1	1 295		2 881
		0.2	9.6	4.0		0.3	15.4	2.7	0.3	0.9		1.7	0.1	2.1	0.05	61.7		99.1
Total	60.6	16	283	99	1	20	2 569	3 644	24	179	1	619	49	1 909	1 772	26 302	4	37 491
CUE		0.3	4.7	1.6	<0.1	0.3	42.4	60.1	0.4	3.0	<0.1	10.2	0.8	31.5	29.2	434.0	0.1	618.7

[a] = captured and observed

[b] = unidentified to species

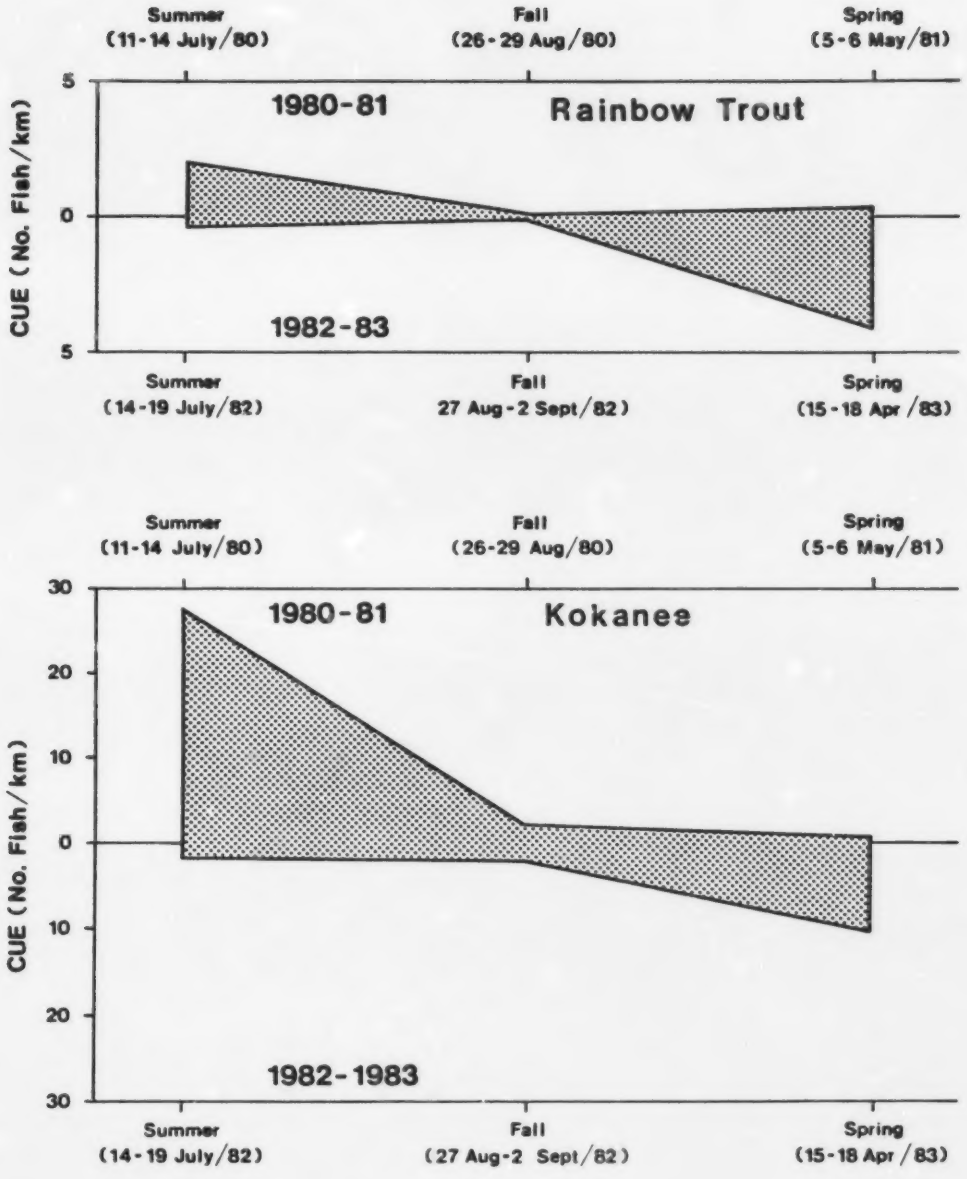


Figure 3.2. Seasonal variation in night electrofishing catches for rainbow trout and kokanee in the Columbia River, for periods 1980-81 and 1982-83.

More mountain whitefish were captured in summer 1980 (CUE = 77.6) than in summer 1982 (CUE = 6.6), although by fall, catches for both years were similar (Figure 3.3). The CUE values were 102.4 for fall 1980 and 104.8 for fall 1982. Catches of mountain whitefish in spring 1983 (CUE = 15.4) were intermediate between spring 1980 (CUE = 6.2) and spring 1981 (CUE = 74.4).

An inverse relationship may exist for catches of mountain whitefish and catches of rainbow trout and kokanee in the spring sampling period. During spring periods when mountain whitefish were relatively abundant (e.g., 1981), catches of rainbow trout and kokanee were low. Insufficient data are presently available to determine if the cause is biologically based (e.g., competition, movement patterns), is related to dissolved gas concentrations, or if sampling biases are responsible.

The largest fluctuation in abundance was recorded for redside shiners. This species was most abundant in the summer and fall periods.

Also of interest is the capture of walleye in the spring of 1983. Walleye had not been captured in either spring 1980 or spring 1981. This may indicate some spawning use of the area by this species.

3.4.2 SPAWNER ENUMERATION

3.4.2.1 Rainbow Trout

Norns Creek

A partial enumeration of rainbow trout spawners moving into Norns Creek was conducted during April and May of 1983. Fifteen adults were captured in the trap near the mouth of Norns Creek, although the trap and associated weir were not fully operational during a portion of the run (Table 3.15). Associated water temperatures and depths at the Norns Creek trapping site are presented in Table 3.16. In addition, backpack electrofishing was conducted at selected locations to augment the number of tagged fish in the creek; five individuals were tagged as a result of electrofishing. On 5 May, electrofishing was conducted throughout the length of Norns Creek to determine the ratio of marked to unmarked specimens.

Escapement estimates of adult rainbow trout entering Norns Creek were made using Chapman's modification of the Peterson method (Ricker 1975). This resulted in a population estimate of 81 rainbow trout spawners. Confidence

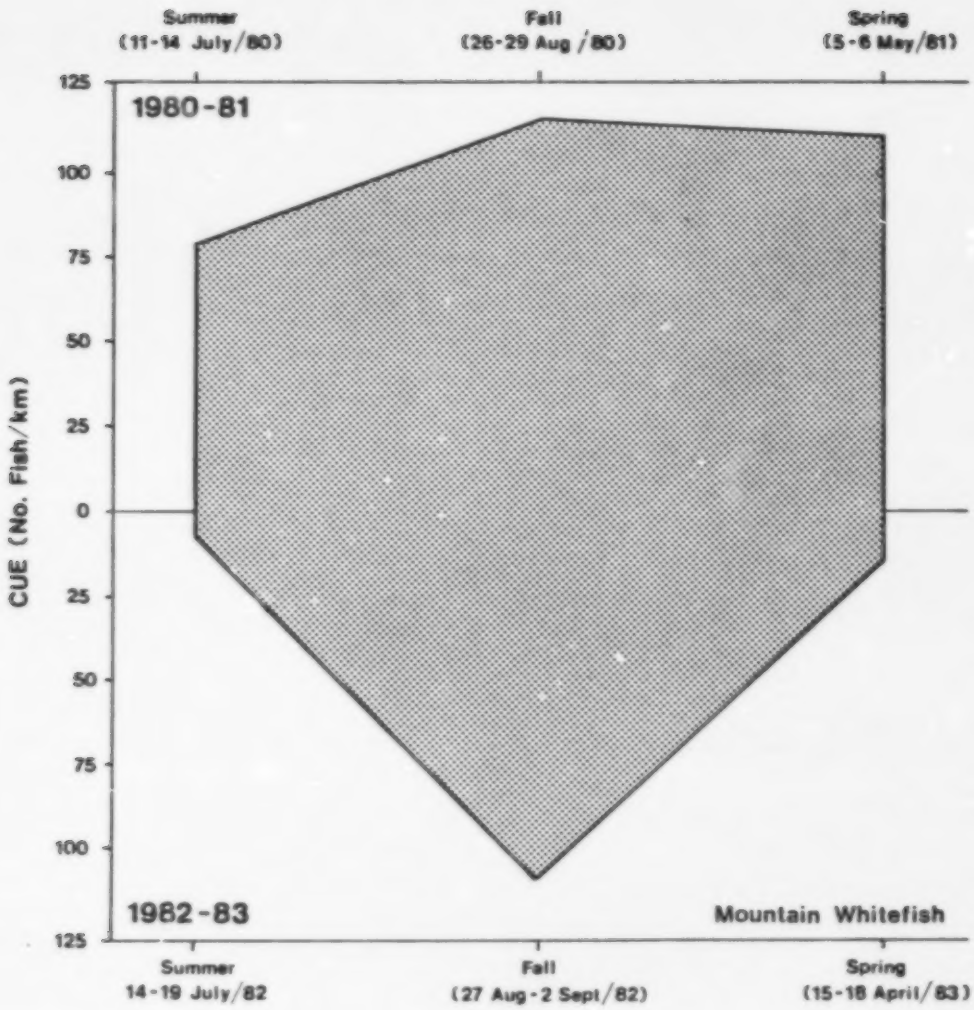


Figure 3.3. Seasonal variation in night electrofishing catches for mountain whitefish in the Columbia River, for the periods 1980-81 and 1982-83.

Table 3.15. Adult rainbow trout captures in Norns Creek, 15 April to 5 May, 1983.

Date	Box Trap Upstream Migrants	Box Trap Downstream Migrants	Back Pack Electrofishing[a]	Comments
April 15	0			Trap installed on 14 April
16	1			
17	6		3	
18	5			
19	0	0		
20	1	0		
21	0	0		Fence partially washed out[b]
22	0	0		Fence repaired
23	1	0		
24	0	0		Fence partially washed out[b]
25	0	0		" "
26	0	0		" "
27	0	0		" "
28	0	0		" "
29	0	0		" "
30	1	0		
May 1	0	0		
2	0	0		
3	0	0		
4	0	0	2	
5	0	0	1	Traps removed

[a]includes only fish captured, not observed

[b]fence repaired daily

Table 3.16. Water temperature and stream depth (at trap site) in Norns Creek, 15 April to 6 May, 1983.

Date	Time (h)	Temperature (°C)	Depth (cm)	Time (h)	Temperature (°C)
April 15	1000	4.5	43	1815	8.5
16	1130	7.5	43	n.d.	n.d.
17	1200	9.5	44	1800	9.2
18	1030	6.0	48	1800	9.0
19	1030	6.0	50	1800	8.4
20	1030	6.0	58	1800	8.0
21	1030	5.5	62	1800	8.0
22	1000	5.5	64	1800	6.0
23	1330	8.5	61	1800	7.3
24	1330	5.5	77	1800	4.5
25	1000	5.0	76	1800	5.0
26	1030	5.0	69	1800	6.0
27	1030	5.5	65	1830	6.5
28	1000	4.3	63	1930	6.5
29	1000	5.0	58	1900	8.0
30	1015	6.5	59	1830	7.0
May 1	1030	6.5	60	1800	8.5
2	0945	5.5	62	1800	7.0
3	0945	5.5	66	1745	7.0
4	0900	5.0	65	1815	7.0
5	0930	4.5	66	1815	8.0
6	1000	5.0			

limits (95%) were 43 and 165; they were derived by treating recaptures as a Poisson variable (Ricker 1975). Although emigration of tagged individuals may have occurred during periods when the trap fence was not operational, this would have decreased the number of marked fish available for recapture.

Population estimates based on multiple census techniques, such as the short Schnabel, modified Schnabel, and Schumacher estimate also were computed. The values obtained ranged from 74 to 83 adult rainbow trout in the creek. Since high water levels reduced fence efficiency, and since the major cause of systematic error in multiple censuses is the effect of recruitment (Ricker 1975), these values should be used only as a general indication of population levels.

The population estimate calculated for spring 1983 was substantially lower than the estimate for spring 1981 (i.e., 262 ± 51); both were determined by similar methods. There are insufficient data available at the present time to determine whether the rainbow trout escapement was abnormally low in 1983.

Champion Creek

Backpack electrofishing surveys were conducted in Champion Creek on 27 April and 4 May to determine the extent of rainbow trout spawning use. Adult rainbow trout were not captured during these surveys.

In 1981, 15 mature rainbow trout were observed in Champion Creek. Ash et al. (1981) noted that movement in 1981 appeared to have commenced when water levels stabilized and water temperatures reached 7°C. In 1983, the surveys were conducted when water levels were receeding after the spring freshet, and maximum water temperature was 5.5°C. Rainbow trout may have moved into the creek after termination of the spring study, when water temperatures were higher.

Other Tributaries

Backpack electrofishing was conducted in Murphy Creek on 3 May 1983. Adult rainbow trout were not captured at that time. Murphy Creek was in the midst of a freshet during the sampling period, and it is likely that water

velocity inhibited upstream movement of adult rainbow trout at that time. Adult rainbow trout were not captured in this creek in spring 1981.

One mature female rainbow trout was captured in Blueberry Creek on 3 May, indicating possible spawning use of this tributary. Adult rainbow trout were not taken from this creek in spring 1981.

Adult rainbow trout were not captured or observed in China Creek during a backpack electrofishing survey on 3 May. Adult rainbow trout were not taken in spring 1981 from China Creek.

Mainstem Columbia and Kootenay Rivers

Potential rainbow trout spawning areas in the Columbia River were surveyed by helicopter on 23 April 1983. Approximately 10 adult rainbow trout were observed over a gravel-cobble bar along the east bank at Km 42 (below the highway bridge crossing). Although other areas between Murphy Creek and the Kootenay River appeared to have suitable substrates, adult rainbow trout were not observed at these sites indicating that hydraulic conditions may not have been suitable for spawning.

Adult rainbow trout were observed holding near a gravel bar immediately downstream of the Highway #3 bridge crossing over the Kootenay River. Spawning adults were enumerated on three different occasions between 17 April and 4 May, 1983; 23 was the maximum number observed. In April of 1981, approximately 30 large rainbow trout were observed at this site.

3.4.2.2 Kokanee

Norns Creek

The maximum number of kokanee observed utilizing Norns Creek for spawning between 30 August and 12 September in 1982 was 226 (Table 3.17). The lower estimate of 92 kokanee recorded on 12 September likely is attributable to freshet conditions and the associated increase in turbidity, in conjunction with predation and post spawning mortality. Numbers of kokanee were greatest in Reach B (Km 1.1 to Km 1.8). At the peak of the kokanee run, large sized individuals made up about 53% of the total number of kokanee using

Table 3.17. Numbers of kokanee spawners enumerated in Norns Creek in 1982.

Date	Water Conditions	Water Temp (°C)	Size	Location and Numbers			
				Reach A (Km 0.0–1.1)	Reach B (Km 1.1–1.8)	Reach C (Km 1.8–2.2)	Total
30 Aug.	good visibility	15	small	4	38	60	102
			large	0	53	18	71
1 Sept.	good visibility	14	small	6	61	39	106
			large	3	108	19	120
12 Sept.	freshest flows, high turbidity and decreased visibility	11	small	0	0	5	5
			large	0	54	33	87

the creek. The small bodied kokanee were more abundant in the creek during the early part of the run than were the large kokanee (i.e., 102 small; 71 large).

The 1982 escapement of kokanee in Norns Creek was approximately one-tenth that of 1980 (Table 3.18). Historical records from 1976 to 1981 indicated from 500 to 5000 kokanee have spawned in Norns Creek in any given year. The 1982 spawning run of kokanee was primarily age 3+, indicating they were progeny of the 1978 spawners. Since spawning escapement into Norns Creek was relatively high (2500 fish) in 1978, the low escapement in 1982 indicates poor spawning success or low survival of the year class.

It is expected that a low escapement of kokanee spawners will occur in Norns Creek in the fall of 1986. This is based in part, on the low spawning escapement in 1982. In addition, a large bank slump occurred in early 1983, causing substantial amounts of sand-silt to be deposited on the substrate throughout the creek. This may have resulted in the smothering of yolk-sac larvae and lead to poor recruitment of this year class (which should be the main contributor to the 1986 fall spawning run).

Other Tributaries

Blueberry, Champion, Murphy and China creeks were all surveyed for the presence of kokanee spawners. Kokanee were not observed in any of these creeks.

Mainstem Columbia River

Kokanee spawn primarily in streams tributary to the Columbia River. Although most spawning in the area likely occurs in Norns Creek, isolated locations in the mainstem Columbia River may have conditions suitable for kokanee spawning. One area that has been identified as a possible spawning site is located along the south shore, close to the apron of the Hugh Keenleyside Dam. In this area, suitably sized gravels are present along the shoreline. During electrofishing surveys in this area during the fall of 1982, small numbers of adult kokanee were captured. However, since these kokanee were not yet ripe, it is not known if they actually spawned at this location.

Table 3.18. Estimates of kokanee escapements in tributaries of the Columbia River, 1976 to 1979 (P. Stent, B.C. Fish and Wildlife Branch, pers. comm.), 1980 (Ash et al. 1981), 1981 (Ash and Luedke 1981), and 1982 (present study). The estimates were obtained through visual enumeration of the kokanee.

	Number of Kokanee		
Year	Norns Creek	Murphy Creek	China Creek
1976	1000		
1977	5000	50	50
1978	2500		50
1979	1500		
1980	2000	5	
1981	500-600		
1982	225-275		

The major drawback associated with spawning in the mainstem Columbia River is the possible dewatering of the kokanee redds. Columbia River water levels in the tailwater of the Hugh Keenleyside Dam vary up to 6 m over the winter which may result in the dessication or freezing of kokanee eggs deposited within the dewatered zone.

3.4.3 FISH MOVEMENTS

Movement data, based on tag returns, have been collected for 13 rainbow trout, one kokanee, two walleye, one largescale sucker and three northern squawfish during the present study (Table 3.19). A breakdown of the tag return data indicated that 60% of the returns were from anglers, 10% were from U.S. Fish and Wildlife Service personnel, and 30% were from the present study team.

The recapture information for rainbow trout indicates 69% of the fish (i.e., nine) were recaptured within 10 km of their original tagging location. Of the remaining 31%, all moved downstream and were recaptured from 21 km to 46 km from the original tagging site. Four of the 13 rainbow trout were recaptured in the second or third year after tagging (Table 3.19). Two of these individuals were taken within 2 km of their tagging site and the other two were captured 31 km and 46 km downstream.

One tag was recovered from a kokanee found among the stomach contents of a bull trout. The kokanee was originally tagged at the base of the Hugh Keenleyside Dam, and the bull trout was caught by an angler within 2 km of the dam.

One walleye tagged near the base of the Hugh Keenleyside Dam was recovered approximately 88 km downstream, at a site approximately 10 km above Lake Roosevelt. Another walleye, tagged below Trail in August 1981, was captured in the Sanpoil River Arm of Lake Roosevelt; it had travelled approximately 200 km downstream in the Columbia River/Lake Roosevelt system and then 16 km up the Sanpoil Arm.

The three northern squawfish and one largescale sucker recaptured during this study all were caught within 5 km of the tagging location.

Table 3.19. Summary of fish recaptures, Columbia River, 1982 and 1983.

Species	Tag Number	Release Date	Recapture Date	Release Location (Km)	Recapture Location (Km)	Approximate Distance Moved (Km)[a]
RT	1878	18 April 1981	30 July 1982	48	Castlegar	-1
RT	1891	19 April 1981	27 July 1982	48	17	-31
RT	1910	21 April 1981	June 1983[b]	48	50	+2
RT	1939	29 April 1981	26 July 1982	48	2	-46
RT	5178	16 April 1983	16 April 1983	50	51	+1
RT	5180	16 April 1983	18 April 1983	50	50	0
RT	5186	16 April 1983	17 July 1983	51	Kootenay R	-6, +2
RT	5192	16 April 1983	18 April 1983	51	50	-1
RT	5213	16 April 1983	29 May 1983	50	50	0
RT	5215	16 April 1983	8 Aug. 1983	50	50	0
RT	5238	17 April 1983	4 July 1983	48	27	-21
RT	5242	17 April 1983	23 May 1983	48	17	-31
RT	362	18 April 1983	30 June 1983	48	53	+5
K	5571	18 April 1983	20 June 1983	56	55	-1
YW	919	20 Aug. 1981	29 May 1982	7	L. Roosevelt	-200, +16
YW	5137	30 Aug. 1982	2 May 1983	56	32 km south of U.S.A. boundary	-88
LSS	5132	27 Aug. 1982	30 Aug. 1982	54	51	-3
NSF	3438	15 July 1982	17 July 1982	56	54	-2
NSF	5133	27 Aug. 1982	16 April 1983	53	50	-3
NSF	5157	1 Sept. 1982	9 July 1983	52	Castlegar	-5

[a] net movement upstream (+); net movement downstream (-)

[b] incomplete creel return

4.0 SUMMARY AND CONCLUSIONS

This study represents part of a continuing program to collect baseline information on the aquatic resources in the lower Columbia River in British Columbia. Through comparison of the results of the present study to those from the previous studies, the following observations or preliminary conclusions relating to the aquatic resources in the study area were noted:

1) Chemical water quality within the study area is considered to be good. Nutrient levels generally were low to moderate, and were higher in the lower sections of the study area possibly reflecting inputs of domestic sewage and Westar Timber Ltd. effluents.

2) Dissolved gas levels in the Columbia River below the Hugh Keenleyside Dam were high whenever discharge was through the sluiceway at the dam. The maximum dissolved gas concentrations monitored during the four survey periods was 124%. Although this dissolved gas level is much lower than the 144% saturation reported by Clark (1977), it would result in gas bubble disease in fish if the fish remained in shallow water for an extended period of time (i.e., longer that a few hours). Symptoms of gas bubble disease were noted in a total of 15 fish during the July sampling period and one fish during the September sampling period. Largescale sucker was the species most commonly affected.

3) Large numbers of the freshwater shrimp Mysis relicta are transported from the Arrow Lakes Reservoir into the Columbia River via the discharge of the Hugh Keenleyside Dam. Mysid entrainment at the dam occurred primarily at night. Peak numbers of mysids were recorded during the July sampling period, with densities reaching $1.98/m^3$ in the sample collected at 2400 h. The density of mysids was lowest during the April 1983 sampling period.

4) The mysids entering the Columbia River provide an important source of food for fish in the study area.

5) Benthic macroinvertebrate densities were highest during the August sampling period. The fauna was dominated by Hydra, oligochaetes, and chironomids. The extensive water level fluctuation in the Columbia River as a result of variations in discharge likely reduces the benthic productivity of the river.

6) The species composition of the fish captured or observed in the study area was similar to that recorded during the previous study.

7) The catch per unit effort (CUE) for rainbow trout in the night electrofishing sections was higher during the spring of 1982 than during the spring of 1981.

8) The CUE for kokanee was high during the summer of 1980 but dropped substantially to very low levels by the spring of 1981. Kokanee abundance in the Columbia River remained low throughout 1981 and 1982 but increased in the spring of 1983. This corresponded with a substantial decrease in the sport fishery catch of kokanee during 1981 and 1982.

9) Walleye were captured during the spring of 1983, indicating that walleye may be spawning in the study area.

10) The numbers of adult rainbow trout spawning in Norns Creek during the spring of 1983 (estimated 81 fish; 95% confidence interval of 43 to 165 fish) was substantially lower than in 1981 (262 ± 51 fish). The reasons for the decline in numbers is unknown but may be related to natural fluctuations in year-class abundance, or may be the result of overharvest of the rainbow trout populations in the river during previous years.

11) Evidence of rainbow trout spawning was observed in the Kootenay River just downstream of the highway bridge, and in the mainstem Columbia River along the east bank below the Highway #3 bridge crossing (Km 42).

12) During the fall of 1982, approximately 225-250 kokanee spawned in Norns Creek. This represented the lowest spawning escapement in Norns Creek during the seven years of record. As a result of the low number of fish spawning during the fall of 1982 and the probable reduced egg survival during the winter of 1982-83 (due to high sediment levels resulting from an upstream bank slump), it is likely that spawning escapement in 1986 will be low.

13) Of 13 tagged rainbow trout that were recaptured during the present study, three had moved downstream of the proposed Murphy Creek damsite. One of the walleye recaptured had moved from the tagging location near the Hugh Keenleyside Dam to a location approximately 32 km downstream of the Canada-U.S.A. border. The kokanee, northern squawfish, and large-scale sucker recaptured were all caught within 5 km of the original tagging location.

Literature Cited

Allen, R.K. and G.F. Edmunds. 1962. A revision of the genus Ephemerella (Ephemeroptera: Ephemerellidae). V. The Subgenus Drunella in North America. Misc. Publ. Entomol. Soc. Am. 3:145-179.

____. 1963. A revision of the genus Ephemerella (Ephemeroptera: Ephemerellidae). VII. The subgenus Serratella in North America. Annals of Entomol. Soc. Am. 56:583-600.

____. 1965. A revision of the genus Ephemerella (Ephemeroptera: Ephemerellidae). VIII. The subgenus Ephemerella in North America. Misc. Publ. Entomol. Soc. Am. 61:1044pp.

Ash, G. and W. Luedke. 1981. Murphy Creek fisheries study. Addendum report - summer/fall 1981 studies. Rep. Prep. for B.C. Hydro, Vancouver, B.C. by R.L. & L. Environ. Serv. Ltd., Edmonton, Alberta. (Revised January 1984). 47pp.

Ash, G., W. Luedke, and B. Herbert. 1981. Fisheries inventory and impact assessment in relation to the proposed Murphy Creek Project on the Columbia River, B.C. Rep. Prep. for B.C. Hydro by R.L. & L. Environ. Serv. Ltd., Edmonton. (Revised January 1984). 329pp.

Baumann, D.W., A.R. Gaufin, and R.F. Sardick. 1977. The stoneflies (Plecoptera) of the Rocky Mountains. Memoirs of the Am. Entomol. Soc. No. 31. 208pp.

Beeton, A.M. 1960. The vertical migration of Mysis relicta in lakes Huron and Michigan. J. Fish. Res. Board Can. 17:517-538.

Bentley, W.W., E.M. Dawley, and T.W. Newcomb. 1976. Some effects of excess dissolved gas on squawfish, Ptychocheilus oregonensis (Richardson). pp.41-46. In: D.H. Fickeisen and M.J. Schneider (eds.). Gas bubble disease. CONF-741033, Tech. Inf. Center, Energy Res. Dev. Admin., Oak Ridge, Tenn. 123pp.

Berrill, M., and C. Lasenby. 1983. Life cycles of the freshwater mysid shrimp Mysis relicta reared at two temperatures. Trans. Am. Fish. Soc. 112:551-553

Blahm, T.H., B. McConnell, and G.R. Snyder. 1976. Gas supersaturation research, National Marine Fisheries Service, Prescott Facility - 1971 to 1974. pp. 11-19. In: D.H. Fickeisen and M.J. Schneider (eds.). Gas bubble disease. CONF-741033, Tech. Inf. Center, Energy Res. Dev. Admin., Oak Ridge, Tenn. 123pp.

British Columbia Fish and Wildlife Branch. N.D. Arrow Lake Creel Census, Summer, 1972. B.C. Fish and Wildl. Br. Unpubl. MS Rep. 13pp.

British Columbia Ministry of Environment. 1979. Kootenay air and water quality study, Phase II. Water quality in the lower Columbia River Basin. Water Investigations Br., Victoria. 238pp.

British Columbia Research. 1977. Limnology of Arrow, McNaughton, Upper Campbell and Williston lakes. Prep. for B.C. Hydro and Power Authority by Div. Appl. Biol., B.C. Res. 186pp.

Clark, M.J.R. 1977. Environmental protection dissolved gas study: Data summary—1977. B.C. Minist. Environ., Pollut. Control Br. 246pp.

Ebel, W.J., H.L. Raymond, G.E. Monan, W.E. Farr, and G.K. Tanonaka. 1975. Effect of atmospheric gas supersaturation caused by dams on salmon and steelhead trout of the Snake and Columbia rivers. Nat. Mar. Fish. Serv., N.W. Fish Center, Seattle, Wash. 111pp.

Edmondson, W.T. (ed.). 1959. Fresh-Water Biology. 2nd Ed. J. Wiley and Sons, N.Y. 1248pp.

Fickeisen, D.H. and J.C. Montgomery. 1978. Tolerances of fishes to dissolved gas supersaturation in deep tank bioassays. Trans. Am. Fish. Soc. 107:376-381.

Gaufin, A.R., W.E. Ricker, M. Miner, P. Milam, and R.A. Hayes. 1972. The stoneflies (Plecoptera) of Montana. Trans. Am. Entomol. Soc. 98:1-161.

Gosho, M.E. 1975. The introduction of Mysis relicta into freshwater lakes (A literature survey). Univ. Wash. Fish. Res. Inst., Circ. 75-2:66pp.

Hughes, B.D. 1978. The influence of factors other than pollution on the value of Shannon's diversity index for benthic macroinvertebrates in streams. Water Res. 12 359-364.

Hynes, H.B.N. 1970. The ecology of running waters. Univ. Toronto. Press, Toronto. 555pp.

International Environmental Consultants (IEC). 1981. Murphy Creek environmental assessment water quality study. Prelim. Rep. Prep. for B.C. Hydro and Power Authority, Vancouver.

Lasenby, D.C., and R.R. Langford. 1972. Growth, life history and respiration of Mysis relicta in an arctic and temperate lake. J. Fish. Res. Board Can. 29:1701-1708.

Lindsay, R.A. 1976. Castlegar Ferry-Keenleyside Dam creel census. B.C. Fish Wildl. Br., Nelson, Unpubl. MS Rep. 4pp.

Lloyd, M., J.H. Zar, and J.R. Karr. 1968. On the calculation of information - theoretical measure of diversity. Am. Midl. Nat. 72(2):257-272.

Mason, W.T. 1973. An introduction to the identification of the chironomid larvae. Anal. Qual. Control Lab., Nat. Environ. Res. Centre, U.S. Environ. Protection Agency. 90pp.

Mauchline, John. 1980. The biology of mysids. Advances in Mar. Biol. 18:1-369.

Meekin, T.K. and B.K. Turner. 1974. Tolerance of salmonid eggs, juveniles and squawfish to supersaturated nitrogen. Wash. Dep. Fish., Tech. Rep. 12:78-126.

Merritt, R.W. and K.W. Cummins. (eds.). 1978. An introduction to the aquatic insects of North America. Kendall/Hunt Publishing. Dubuque, Iowa. 441pp.

Morgan, M.D. 1980. Life history characteristics of two introduced populations of Mysis relicta. Ecology 60:551-561.

_____. 1981. Abundance, life history, and growth of introduced populations of the opossum shrimp (Mysis relicta) in subalpine California lakes. Can. J. Fish. and Aquat. Sci. 38:989-993.

Morgan, M.D., and A.M. Beeton. 1978. Life history and abundance of Mysis relicta in Lake Michigan. J. Fish. Res. Board Can. 35:1165-1170.

Morgan, M.D., S.T. Threlkeld, and C.R. Goldman. 1978. Impact of the introduction of kokanee (Oncorhynchus nerka) and opossum shrimp (Mysis relicta) on a subalpine lake. J. Fish. Res. Board Can. 35:1572-1579.

Mundie, J.H. 1959. The diurnal activity of the larger invertebrates at the surface of Lac la Rouge, Saskatchewan. Can. J. Zool. 37:945-956.

Pennak, R.W. 1978. Freshwater invertebrates of the United States. 2nd Ed. J. Wiley and Sons, N.Y. 803pp.

Ricker, W.E. 1959. Additional observations concerning residual sockeye and kokanee (Oncorhynchus nerka). J. Fish. Res. Board Can. 16:897-902.

_____. 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Board Can., Bull. 191:382pp.

Taylor, G.N., L.S. Cole, and W.F. Sigler. 1957. Galvanotaxis response of fish to pulsating direct current. J. Wildl. Manage. 21:201-213.

Thompson, R.B. 1959. Food of the squawfish, Ptychocheilus oregonensis (Richardson) of the Columbia River. U.S. Fish Wildl. Serv., Fish. Bull. 158:43-58.

Usinger, R.L. (ed.) 1956. Aquatic insects of California. Univ. Calif. Press, Berkeley. 508pp.

Vincent, R. 1971. River electrofishing and fish population estimates. Prog. Fish-Cult. 33:163-169.

Water Survey of Canada. 1983. Surface water data British Columbia 1982. Inland Waters Directorate, Water Resources Branch, Environment Canada, Ottawa. 334pp.

Weber, C.I. (ed.). 1973. Biological field and laboratory methods for measuring the quality of surface waters and effluents. U.S. Environ. Protection Agency. Rep. EPI-670/4-73-001.

Weitkamp, D.E., and M. Katz. 1980. A review of dissolved gas supersaturation literature. Trans. Am. Fish. Soc. 109:659-702.

Wiggins, G.B. 1977. Larvae of the North American caddisfly genera (Trichoptera). Univ. Toronto Press, Toronto. 401pp.

APPENDIX A

TERMS OF REFERENCE

MURPHY CREEK PROJECT

Terms of Reference
WATER QUALITY AND AQUATIC RESOURCES

Study Area

Studies carried out on the proposed Murphy Creek project should be confined to the Columbia River between Keenleyside dam and Trail.

(a) Inventory

(i) Water Quality

1. Seasonal monitoring of quality and macronutrients including: pH, conductivity, total solids, total dissolved solids, total suspended solids, total phosphate, total dissolved phosphate, particulate phosphate, dissolved orthophosphate, total nitrate/nitrite (N), dissolved nitrate/nitrite (N), particulate nitrate/nitrite (N) and ammonia.

2. Monitoring in situ of supersaturated gases.

3. Water samples should be sent to B.C. Hydro Surrey Lab for analysis.

(ii) Invertebrates

1. Seasonal recruitment of Mysis relicta from Arrow Lake and use in the Murphy Creek study area should be determined during spring and summer.

2. Benthic samples in a few selected sites in the study area should be acquired to augment the mysid data.

(iii) Fisheries Resources

1. Spawner enumerations of the 1982 autumn kokanee run and the 1983 spring rainbow trout run in tributaries and where feasible in the mainstem Columbia River.

2. Seasonal variation in night electrofishing catches at sites used in the initial aquatic resources study. Studies should be carried out in summer, autumn and spring of 1982 and 1983 respectively.

3. Estimates of numbers of fish passing from Arrow Lake into the study area should be carried out.

(b) Effect of Development

1. Assess the range of natural fluctuations in fish populations over the period of study from 1980 to 1983.

2. Estimate the level of recruitment of fishes and invertebrates into the study area from Arrow Lake.

3. Determine the seasonal range in water quality parameters as listed above.

APPENDIX B

STOMACH CONTENT ANALYSIS

Table B-1. Stomach content analysis of selected fish species captured in the Columbia River, 1982 and 1983.

Species	Kokanee			Rainbow Trout			Mountain Whitefish		
Date	July 1982	August 1982	April 1983	July 1982	August 1982	April 1983	July 1982	August 1982	April 1983
No. Examined (n)	12	2	21	6	1	3	22	27	21
Fullness Points (F)	102	18	190	35	8	18	198	283	197
% of Stomach Volume Occupied (F/n x 20)	42.5	45.0	45.2	29.2	40.0	28.7	45.0	48.7	46.9
Food Items (% by Volume)									
Mysids	88.8	94.4	84.3	62.9	-	62.5	40.4	53.8	-
Zooplankton	13.7	-	7.9	-	-	-	-	-	-
Gastropods	-	-	-	-	-	-	-	-	2.0
Pelecypods	-	-	-	-	-	-	-	-	1.9
Ephemeroptera	14.2	-	-	2.9	-	-	32.3	2.5	4.1
Trichoptera	2.9	-	6.3	-	-	-	7.1	16.9	5.1
Diptera	0.5	5.6	1.8	-	-	-	14.1	25.5	86.7
Coleoptera	-	-	-	5.7	25.0	-	-	-	1.0
Hemiptera	-	-	-	29.0	-	-	-	-	-
Hymenoptera	-	-	-	-	-	37.5	-	-	-
Insect Remains	-	-	-	8.6	75.0	-	8.1	3.0	8.5
Fish	-	-	-	-	-	-	-	-	-
Detritus	-	-	-	-	-	-	-	-	-

Species	Walleye			Northern Squawfish			Peamouth		
Date	July 1982	August 1982	April 1983	July 1982	August 1982	April 1983	July 1982	August 1982	April 1983
No. Examined (n)			1	4		2	7	2	
Fullness Points (F)			8	20		0	14	2	
% of Stomach Volume Occupied (F/n x 20)			40.0	25.0		0	10.0	5.0	
Food Items (% by Volume)									
Mysids			-	-		-	-	-	
Zooplankton			-	-		-	3.6	-	
Gastropods			-	-		-	-	-	
Pelecypods			-	-		-	-	-	
Ephemeroptera			-	-		-	10.7	-	
Trichoptera			-	-		-	3.3	-	
Diptera			-	-		-	-	-	
Coleoptera			-	-		-	-	-	
Hemiptera			-	-		-	-	-	
Hymenoptera			-	-		-	-	-	
Insect Remains			-	-		-	-	-	
Fish			100.0	80.0	-	-	-		
Detritus			-	20.0	-	85.7	100.0		

Species	Redside Shiner		
Date	July 1982	August 1982	April 1983
No. Examined (n)	31	20	
Fullness Points (F)	364	182	
% of Stomach Volume Occupied (F/n x 20)	58.7[a]	45.5[b]	
Food Items (% by Volume)			
Mysids	1.9	7.7	
Zooplankton	3.3	8.8	
Gastropods	-	-	
Pelecypods	-	-	
Ephemeroptera	34.6	3.3	
Trichoptera	3.3	41.2	
Diptera	4.4	9.9	
Coleoptera	-	-	
Hemiptera	-	-	
Hymenoptera	-	-	
Insect Remains	30.2	23.6	
Fish	1.1	-	
Detritus	3.8	-	

a includes 17.3% nematodes

b includes 7.7% nematodes

c includes 14.1% nematodes

APPENDIX C

ABUNDANCE AND COMPOSITION OF BENTHIC INVERTEBRATES

Table C-1. Abundance and composition of benthic invertebrates collected in Hess cylinder samples (area = 0.1 m^2) at Site H1, Columbia River during July and August 1982, and April 1983.

Taxa	21 July				30 August				29 April			
	1	2	3	$\bar{x}$	1	2	3	$\bar{x}$	1	2	3	$\bar{x}$
COELENTERATA												
Hydra	47	65	21	44.3	1194	1150	579	974.3	6	22	4	10.7
NEMATODA	-	2	1	1.0	-	2	5	2.3	4	5	6	5.0
PLATYHELMINTHES												
Turbellaria									1	-	-	0.3
ANNELIDA												
Oligochaeta	137	29	13	59.7	197	166	52	138.3	67	63	17	49.0
Hirudinea									-	-	1	0.3
MOLLUSCA												
Pelecypoda									-	-	4	1.3
Sphaeriidae									4	4	-	2.7
Gastropoda												
Valvatidae												
Valvata					1	-	-	0.3				
Lymnaeidae												
Lymnaea									1	-	-	0.3
ARTHROPODA												
Arachnida												
Acari									1	4	-	1.7
Insecta												
Ephemeroptera												
Ephemerella					-	-	1	0.3				
Ameletus									74	1	15	30.0
Plecoptera	2	-	-	0.7								
Hemiptera												
Corixidae	1	-	-	0.3					-	2	-	0.7
Trichoptera												
Dolophilodes									-	1	-	0.3
Mystacides									-	1	-	0.3
Lepidostoma									-	1	-	0.3
Collembola									1	1	-	0.7
Coleoptera												
Dytiscidae					1	-	-	0.3				
Gyrinidae	-	1	-	0.3								
Diptera												
Ceratopogonidae	2	-	-	0.7								
Chironomidae									-	1	-	0.3
Tanypodinae	6	-	-	2.0	5	-	4	3.0	-	2	-	0.7
Orthocladiinae	21	9	-	10.0	134	81	154	123.0	-	11	1	4.0
Corynoneura	5	-	1	2.0					7	-	-	2.3
Chironominae					1	-	-	0.3				
Chironomini					5	1	-	2.0				
Tanytarsini					17	5	28	16.7	1	4	2	2.3
pupae	1	3	-	1.3	14	6	3	7.7				
Total/sample	**222**	**109**	**36**	**122.3**	**1569**	**1411**	**826**	**1268.7**	**163**	**119**	**45**	**109.0**
Total/m^2	**2220**	**1090**	**360**	**1223**	**15690**	**14110**	**8260**	**12687**	**1630**	**1190**	**450**	**1090**

Table C-2. Abundance and composition of benthic invertebrates collected in Hess cylinder samples (area = 0.1 m^2) at Site H2, Columbia River during July and August 1982, and April 1983.

Taxa	21 July				30 August				29 April			
	1	2	3	$\bar{x}$	1	2	3	$\bar{x}$	1	2	3	$\bar{x}$
COELENTERATA												
Hydra	44	188	173	135.0	367	650	513	510.0	2	1	6	3.0
NEMATODA	1	-	-	0.3					33	24	16	24.3
ANNELIDA												
Oligochaeta	49	9	28	28.7	9	14	7	10.0	17	7	14	12.7
MOLLUSCA												
Gastropoda												
Lymnaeidae												
Lymnaea					-	-	1	0.3				
ARTHROPODA												
Arachnida												
Acari									2	-	-	0.7
Insecta												
Ephemeroptera												
Ephemerella	-	-	1	0.3	-	1	-	0.3	4	17	9	10.0
Baetis									-	4	2	2.0
Ameletus	-	3	1	1.3					4	33	14	17.0
Paraleptophebia									3	4	1	2.7
Baetidae									-	-	6	2.0
Heptageniidae									16	20	9	15.0
Plecoptera												
Chloroperlidae									-	6	2	2.7
Nemouridae									1	3	2	2.0
Trichoptera												
Arctopsyche									-	1	-	0.3
Limnephilus									1	1	2	1.3
Hydropsychidae					-	-	1	0.3				
Collembola									2	2	1	1.7
Coleoptera												
Elmidae									3	-	1	1.3
Dytiscidae	-	1	-	0.3								
Diptera									-	-	1	0.3
Tipulidae												
Ormosia									-	-	1	0.3
Simuliidae									-	1	-	0.3
Empidae									-	1	1	0.7
Chironomidae									-	-	2	0.7
Tanypodinae					1	-	-	0.3	7	7	7	7.0
Orthocladiinae	1	-	1	0.7	9	10	6	8.3	35	46	36	39.0
Corynoneura									2	4	7	4.3
Chironominae												
Chironomini									16	7	5	9.3
Tanytarsini									19	27	40	28.7
pupae	1	-	-	0.3	2	-	-	0.7	1	4	1	2.0
Total/sample	**96**	**201**	**204**	**167.0**	**388**	**675**	**528**	**530.3**	**168**	**218**	**186**	**190.7**
Total/m^2	**960**	**2010**	**2040**	**1670**	**3880**	**6750**	**5280**	**5303**	**1680**	**2180**	**1860**	**1907**

Table C-3. Abundance and composition of benthic invertebrates collected in Hess cylinder samples (area = 0.1 m^2) at Site H3, Columbia River during July and August 1982, and April 1983.

Taxa	20 July				29 August				28 April			
	1	2	3	$\bar{x}$	1	2	3	$\bar{x}$	1	2	3	$\bar{x}$
COELENTERATA												
Hydra	2	2	1	1.7	469	24	39	177.3	2	-	1	1.0
NEMATODA	-	-	1	0.3	1	2	-	1.0	-	2	1	1.0
ANNELIDA												
Oligochaeta	4	6	8	6.0	36	28	16	26.7	-	1	8	3.0
MOLLUSCA												
Pelecypoda												
Sphaeriidae									-	1	2	1.0
ARTHROPODA												
Arachnida												
Acari	-	1	1	0.7					4	-	-	1.3
Insecta												
Ephemeroptera												
Ephemerella	6	14	6	8.7	1	-	-	0.3	4	3	5	4.0
Baetis	8	2	1	3.7	2	1	-	1.0	1	2	1	1.3
B. tricaudatus	-	-	2	0.7	-	1	-	0.3				
Pseudocloeon	4	5	2	3.7	1	-	-	0.3				
Heptageniidae					3	1	1	1.7				
Plecoptera									-	1	-	0.3
Trichoptera					-	1	-	0.3				
Hydropsyche									2	-	-	0.7
Cheumatopsyche	3	-	6	3.0					-	4	7	3.7
Brachycentrus	-	1	-	0.3								
Hydroptilidae					3	35	-	12.7				
Hydropsychidae					1	25	16	14.0				
Diptera												
Tipulidae	1	-	-	0.3								
Hexatoma	-	-	1	0.3								
Antocha									1	-	-	0.3
Simuliidae	-	-	1	0.3	1	3	-	1.3	-	2	2	1.3
Chironomidae												
Tanypodinae	1	2	-	1.0	-	3	-	1.0				
Orthocladiinae	33	26	18	25.7	10	22	3	11.7	11	18	13	14.0
Corynoneura					3	-	-	1.0				
Chironominae												
Chironomini					-	1	1	0.7	1	-	-	0.3
Tanytarsini	2	1	1	1.3					-	1	..	0.3
pupae	-	3	-	1.0	1	2	1	1.3	1	3	1	1.7
Total/sample	64	62	49	58.3	532	149	77	252.7	27	38	41	35.3
Total/m^2	640	620	490	583	5320	1490	770	2527	270	380	410	353

Table C-4. Abundance and composition of benthic invertebrates collected in Ekman grab samples (area = 232 cm^2) at Site E1, Columbia River during July and August 1982, and April 1983.

Taxa	20 July				29 August				29 April			
	1	2	3	$\bar{x}$	1	2	3	$\bar{x}$	1	2	3	$\bar{x}$
COELENTERATA												
Hydra	404	3	283	230.0	199	338	88	208.3	8	3	1	4.0
NEMATODA[a]	2	-	4	2.0	1	4	5	3.3	22	37	16	25.0
PLATYHELMINTHES												
Turbellaria									1	-	1	0.7
ANNELIDA												
Oligochaeta	38	5	140	61.0	33	44	37	38.0	156	47	24	75.7
Hirudinea									-	-	1	0.3
MOLLUSCA												
Pelecypoda									-	-	4	1.3
Sphaeriidae									4	4	-	2.7
Pisidium					1	1	-	0.7				
Gastropoda												
Valvata	4	-	-	1.3	1	-	2	1.0	15	11	4	10.0
Lymnaea					-	-	1	0.3				
Gyraulus					2	-	3	1.7	1	1	-	0.7
Helisoma	-	-	1	0.3								
ARTHROPODA												
Insecta												
Ephemeroptera												
Ephemerella	1	-	1	0.7								
Hemiptera												
Corixidae					-	-	1	0.3				
Trichoptera												
Lepidostoma									1	-	2	1.0
Diptera	-	-	2	0.7								
Ceratopogonidae									-	2	1	1.0
Chironomidae									9	8	6	7.7
Tanypodinae	5	1	1	2.3	1	2	1	1.3	9	7	2	6.0
Orthocladiinae	1	1	3	1.7	2	6	13	7.0	12	11	9	10.7
Chironominae									16	-	-	5.3
Chironomini	1	-	-	0.3	-	1	1	0.7	-	5	6	3.7
Tanytarsini	1	-	16	5.7	5	3	19	9.0	37	24	13	24.7
pupae	-	-	3	1.0	1	6	2	3.0				
Total/sample	457	10	454	307.0	246	405	173	274.7	291	160	90	180.3
Total/m^2	19676	431	19547	13218	10592	17438	7449	11827	12529	6889	3875	7763

[a]number of nematodes not reflective of actual abundance since size of organism smaller than mesh opening.

Table C-5. Abundance and composition of benthic invertebrates collected in Ekman grab samples (area = 232 cm^2) at Site E2, Columbia River during July and August 1982, and April 1983.

Taxa	20 July				30 August				28 April			
	1	2	3	$\bar{x}$	1	2	3	$\bar{x}$	1	2	3	$\bar{x}$
COELENTERATA												
Hydra	10	-	-	3.3	-	88	1	29.7				
NEMATODA	-	1	-	0.3					1	5	5	3.7
ANNELIDA												
Oligochaeta	22	-	-	7.3	9	3	2	4.7	-	6	2	2.7
MOLLUSCA												
Pelecypoda												
Sphaeriidae									-	-	1	0.3
Gastropoda												
Planorbidae												
Gyraulus					-	-	1	0.3				
ARTHROPODA												
Insecta												
Ephemeroptera												
Ephemerella									-	-	2	0.7
Trichoptera												
Hydropsychidae	-	1	-	0.3	-	1	1	0.7				
Diptera												
Chironomidae									-	7	4	3.7
Tanypodinae									-	2	4	2.0
Orthocladiinae	4	-	-	1.3	8	6	2	5.3	-	21	12	11.0
Chironominae												
Chironomini	-	3	-	1.0	4	-	-	1.3	1	6	7	4.7
Tanytarsini	6	-	-	2.0	-	2	1	1.0	1	2	3	2.0
pupae	2	-	-	0.7	-	-	1	0.3				
Total/sample	**44**	**5**	**0**	**16.3**	**21**	**100**	**9**	**43.3**	**3**	**49**	**40**	**30.7**
Total/m^2	**1894**	**215**	**0**	**702**	**904**	**4306**	**388**	**1864**	**129**	**2110**	**1722**	**1322**

APPENDIX D

ELECTROFISHING CATCH AND CUE

Table D-1. Electrofishing catch and CUE (No. fish/km) for sample sections in the Columbia River, 15-19 July 1983.

Section (Km)	Date	Distance (km)	Time (s)	Number[a]																Total Fish	CUE #/km
				YN	S	RT	LN	DV	Wh	Suckers[b]	LMS	LSS	RLS	NSF	LSNG	PS	PM	RSS	Carp		
DS-18 (51.7-49.8)	18 July	1.9	1143		11				2	42	1	6		34	6	5	63	34		193	101.6
	19 July	1.9	1567		3	2			2	15		3		22	2	15	7	22		93	48.9
DS-19 (53.1-51.7)	15 July	1.4	1361					1	9	8	2	5		5	6		23			69	49.3
	18 July	1.4	2316		1	1	1	1	6	21		9		25	3	46	42	20		180	128.6
DS-20 (54.1-53.1)	15 July	1.0	933					1	13	10		9		2	2	1	34		1	73	73.0
	18 July	1.0	933		8	2			7	9		11		11		2	18	25		93	93.0
DS-21 (55.3-54.1)	15 July	1.1	1038	1		2		1	32	18	1	14		18	5	7	51	81		243	220.9
	17 July	1.1	1382		3					17		17		88	5	36	88	25		232	201.8
DS-22 (55.9-55.3)	16 July	0.7	1078	1				2	12		1	1	1	3	4		8			33	47.1
	17 July	0.7	884		1			1	2		1				1			5		11	15.7
DS-26 (69.6-69.2)	18 July	0.6	103						1											1	1.7
	19 July	0.6	160		3				2	17	1	6		6	1	20	98	15		163	271.7
DS-27 (50.6-49.8)	18 July	0.8	517						1								3		1	5	6.3
	19 July	0.8	1378		3				17	31		7		14		31	75			178	222.5
DS-28 (51.9-50.6)	16 July	1.3	1171						2	76		18		8		22	104	15	1	246	180.3
	18 July	1.3	1131						1	26		11		7		61	67	35		208	150.3
DS-29 (56.2-55.8)	15 July	0.8	377			1								4			3			8	13.3
	18 July	0.8	338											2			3	12		17	28.3
DS-30 (56.3-56.2)	15 July	0.3	186							2		3		6				270		281	936.7
	18 July	0.3	536	1	4			1		3	1	2		3	2			457		474	1580.0
Totals		15.4		3	37	8	1	8	120	304	6	122	1	183	37	248	700	1006	3	2780	143.8
CUE (no./km)				0.2	1.9	0.4	0.05	0.4	6.6	15.7	0.4	6.3	0.05	9.4	1.0	12.4	36.1	51.0	0.2		

[a]Total fish encountered (captured and observed).
[b]Observed, not identified to species.

Table D-1. Electrofishing catch and CUE (No. fish/km) for sample sections on the Columbia River, 27 August - 2 September 1982.

Section (Km)	Date	Distance (km)	Time (s)	Number[a]																Total Fish	CUE fish/km
				YW	E	RT	LW	DY	NW	Suckers[b]	LMS	LSS	BLS	NSP	LSNS	PS	PM	RBS	Carp		
ES-17 (68.9-68.1)	31 Aug.	0.8	930			1			4	1				1			1			8	10.0
ES-18 (61.7-68.8)	30 Aug.	1.0	1350	1					96	133	3	1		35	4	75	32	1060	1	1372	723.1
	1 Sept.	1.0	1500	2	3	1			400	2				77		100	104	1502		2357	1187.0
ES-19 (53.1-61.7)	30 Aug.	1.4	1080					1	110	205		1		67		50	150	2730		3404	2431.4
	1 Sept.	1.4	1530		2				200	46				36		135	93	2806		3377	2340.7
ES-20 (54.1-53.1)	27 Aug.	1.0	840		2				19	815	1			11	3	151	212	2083		2998	2268.0
	31 Aug.	1.0	885		2			1	103	324	2	7		30		157	100	2513		3813	3013.0
ES-21 (55.2-54.1)	27 Aug.	1.1	730		7				6	9	1	1		1			11	60		96	85.6
	31 Aug.	1.1	1440	1	13			1	6	40		2		50	1	93	77	1604		1827	1600.9
ES-22 (55.9-55.2)	27 Aug.	0.7	841	1	4				3	1		2					2			13	18.6
	31 Aug.	0.7	762		1				0	4								2		13	18.6
ES-26 (69.8-69.2)	31 Aug.	0.6	922		3				70	100		5		22		30	31	104		816	1360.0
	2 Sept.	0.6	804						69	93	1	2		10		25	75	490		666	1110.0
ES-27 (70.6-69.8)	31 Aug.	0.9	780	1					90	43		1		10		25	17	450		601	751.2
	2 Sept.	0.8	837			1			177	181				25		200	21	1501		2405	3031.5
ES-28 (51.9-70.6)	30 Aug.	1.3	1540		1				9	230		7		30		101	4	1000		1485	1038.0
	1 Sept.	1.3	1571			2			300	732		2		30		500	152	2500		4336	3250.5
ES-29 (54.2-51.8)	30 Aug.	0.6	334		2											5		10		17	30.3
	1 Sept.	0.6	347		4	1					1	2		4		14	2	83		111	185.0
ES-30 (56.5-54.2)	30 Aug.	0.3	917	1				1	1			2		1				1012		1019	3396.7
	1 Sept.	0.3	495	2						102	2	1		6		20	5	1900		2036	6783.3
Totals		20.2		8	44	6	0	5	2115	3394	10	38	0	602	8	1625	1071	24001	1	33931	1614.9
CUE (no./km)				0.4	1.3	0.3	-	0.2	104.8	183.8	0.5	1.9	-	19.9	0.4	80.4	53.0	1186.2	0.05		

[a]Total fish encountered (captured and observed).
[b]Observed, not identified to species.

Table D-3. Electrofishing catch and CUE (No. fish/h.o) for sample sections on the Columbia River, 15-19 April 1991.

Section (River mile)	Date	Distance (km)	Time (s)	Number[a]																Total Fish	CUE (fish/km)
				TW	E	BT	LM	SM	MW	Sunfish[b]	LMB	SMB	PLE	WSP	LSNG	PS	PM	RSD	Carp		
ES-34 (51.7-48.6)	16 April	1.9	1940		1	5		1	8	1				7		4				27	14.3
	17 April	1.0	2160	1	9	8				1		1		3						18	9.5
ES-29 (53.1-51.7)	15 April	1.4	1475			1			3	1	1	1		6				20		34	24.3
	17 April	1.4	1380		6	1			1	1				1						11	7.9
ES-30 (54.1-53.1)	15 April	1.0	930			1		1		3		1								6	6.0
	17 April	1.0	1010		3	1			6	3	1	1		1						15	15.0
ES-31 (56.3-54.1)	15 April	1.1	1322			4			19					1		5		31		60	73.7
	17 April	1.1	1370		3	4		1	26	1								30		64	76.4
ES-25 (55.9-55.0)	15 April	0.7	711					1	7	1										9	12.9
	17 April	0.7	790		1	2			5											8	12.9
ES-35 (68.3-67.3)	17 April	0.8	630			5			25	6					1					35	62.8
	18 April	0.9	630			3			16	10		1								30	37.5
ES-36 (69.9-68.3)	17 April	0.6	1140	1	1	15			27	4		1		1		5		5		60	115.0
	18 April	0.6	960			6			55	9	1	4		4	1			15		97	161.7
ES-37 (70.9-69.8)	16 April	0.9	1035		5	19			26	5	1	1		6		5				66	82.5
	18 April	0.8	1334		39	6		1	38	6		3		3		19	1	29		108	135.0
ES-38 (51.9-50.8)	16 April	1.3	1494		13	11			5	1						5		32		6	52.3
	18 April	1.3	960		33	6		1	21	3				3		19		76		160	107.7
ES-39 (56.7-55.8)	16 April	0.6	470						4											4	6.7
	18 April	0.6	180		13				1									2		16	26.7
ES-38 (56.9-56.7)	15 April	0.3	896		10			1	2									22		35	116.7
	18 April	0.3	331		96				20									1002		1116	3720.0
Totals		21.0		4	360	86		7	324	66	6	19		35	3	44	1	1295		2081	
CUE (no./km)				0.2	9.0	4.0		0.3	15.4	2.7	0.3	0.9		1.7	0.1	2.1	0.05	61.7		99.1	

[a]Total fish encountered (captured and observed).
[b]Observed, not identified to species.

POOR

QUALITY

ORIGINAL